Domain Engineering Sciences
Rte du Rawyl 47
CH-1950 Sion 2
Phone +41 27 606 85 11
Fax +41 27 606 85 75
info@hevs.ch

www.hevs.ch

Degree Course Systems Engineering

Option Infotronics

Diploma 2010

Yannick Salamin

USB-SPI Translator

Professor	Christophe Bianchi
Expert	Lixin Ran

Lieu, date de la remise du rapport

☒ FSI ☐ FTV	Année académique / *Studienjahr* **2009/10**	No TD / *Nr. DA* **it/2010/31**
Mandant / *Auftraggeber* ☐ HES—SO Valais ☐ Industrie ☒ Etablissement partenaire **Zhejiang University**	Etudiant / *Student* **Yannick Salamin**	Lieu d'exécution / *Ausführungsort* ☐ HES—SO Valais ☐ Industrie ☒ Etablissement partenaire
Professeur / *Dozent* **Christophe Bianchi**	Expert / *Experte* (données complètes) **Prof. Lixin Ran**	
Travail confidentiel / *vertrauliche Arbeit* ☐ oui / ja [1] ☒ non / nein		

Titre / *Titel*

USB-SPI translator

This work involves a transparent communication between a standard USB port and multiple standard SPI ports. Although it is a small sub-system of a steering phased array antenna, it can also be used in all other similar applications.

The USB interface has become the major communication port for computers. However, USB is still not widely used in MCU world, in which the main serial communication protocols are RS232, I^2C and SPI. Therefore it is still inconvenient for the interconnection between a computer and an MCU-based hardware. In this work, a Future technology's USB Serial UART interface chip, i.e., FT232R, and an MCU (TI's MSP430 or Atmel's ATmega 88) with a standard SPI port will be utilized to realize a USB-SPI translator, which could provide the hardware connection and transparent data transmission functions.

The work consists of following part:

— Design, fabricate and debug a small hardware to realize the electrical connection between a standard USB port and multiple standard SPI ports;

— Write a simple firmware code for the MCU connected with the FT232R to realize the translation between a UART protocol to SPI protocol;

— Write a demo program to realize the two-way transparent data transmission between computer and MCUs by calling the driver provided by Future Technology.

Délais / *Termine*

Attribution du thème / *Ausgabe des Auftrags:* 22.02.2010	Remise du rapport / *Abgabe des Schlussberichts:* 12.11.2010, 12:00
Remise du rapport intermédiaire / *Zwischenbericht:* 07.05.2010, 17:00	Exposition publique / *Ausstellung Diplomarbeiten:* —
Défense intermédiaire / *Zwischenverteidigung:* 21.05.2010	Défense orale / *Mündliche Verteidigung:* Semaine 47 / *Woche 47*

Signature ou visa / *Unterschrift oder Visum*

Responsable de la filière
Leiter des Studiengangs: .....

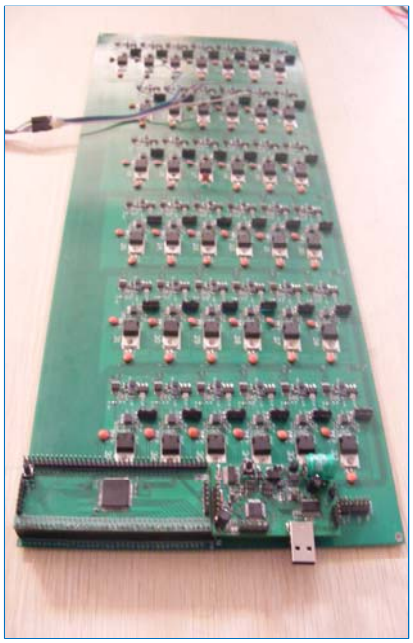
[1] Etudiant/*Student*: Yannick S.

[1] *Par sa signature, l'étudiant-e s'engage à respecter strictement la directive et le caractère confidentiel du travail de diplôme qui lui est confié et des informations mises à sa disposition.*
Durch seine Unterschrift verpflichtet sich der Student, die Richtlinie einzuhalten sowie die Vertraulichkeit der Diplomarbeit und der dafür zur Verfügung gestellten Informationen zu wahren.

Rapport reçu le / *Schlussbericht erhalten am* ..... Visa du secrétariat / *Visum des Sekretariats* .....

Haute Ecole Spécialisée de Suisse occidentale
Fachhochschule Westschweiz
University of Applied Sciences Western Switzerland

USB-SPI Translator



Graduate Salamin Yannick

Bachelor's Thesis
| 2010 |

Degree course
Systems Engineering

Field of application
Infotronic

Supervising professor
Prof. Bianchi Christophe
christophe.bianchi@hevs.ch

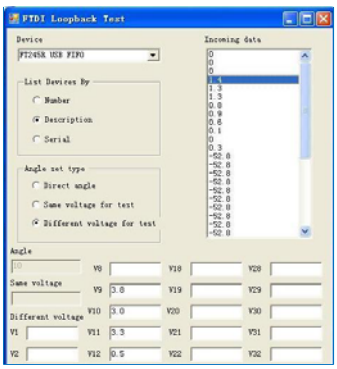
Partner
Zhejiang University

Objectives

The project involves the design of a communication interface between a computer and 37 serial interfaced D/A Converters to update their outputs and also process feedback information from the DACs outputs.

Methods / Experiences / Results

A USB controller (FT245R) is used for the USB communication between the computer and the processing unit (ATmega88). The user is able to send the DACs update information toward the microcontroller which sends the digital values to the DACs. A CPLD device is used to select multiple channels of 37 DACs. The MCU can sample the DACs output voltage via its built-in A/D converter and then send the information to the computer in order to be displayed for the user.
Two hardware boards are designed and fabricated. The main board, *USB-SPI Translator* which provides the power and data processing functions, is a general USB to SPI communication interface board. The other board is in charge of the DACs channels selection. After the realization of the hardware boards, firmware for the data processing unit (MCU) and the CPLD are written.
Some experiments about the whole system demonstrate that the DACs are able to be updated individually with a desired voltage. The precision of the DACs outputs is about one decimal. The MCU can get a 10-bits digital value of the DACs output. The digitalized DACs outputs are transmitted to the computer and displayed for the user.



The graphical user interface allowing the user to send information toward the translator and read the feedback information.

Experimental test set up. The user can type in the information on the computer, send them to the system and then test the DACs output with the multi-meter.

HES-SO Valais
Route du Rawyl 47
1950 Sion

Phone 027 606 85 11
Website www.hevs.ch

Table of Contents

Acronyms

DAC Digital to Analog Converter
ADC Analog to Digital Converter
SPI Serial Peripheral Interface
FIFO First In First Out
CPLD Complex Programmable Logic Device
IC Integrated Circuit
JTAG Joint Test Action Group
ISP In-System Programmable
GUI Graphical User Interface
MCU Micro-Controller Unit

1 Introduction

Nowadays the most used communication interface for computer is USB. However, USB is still not widely used in embedded systems, in which serial communication interfaces as RS232 or SPI are mainly used. Therefore interconnection between computers and embedded systems is still an inconvenience and needs some translation interface in order to connect the equipment's together.

The AEM group of the Zhejiang University is a laboratory specialized in applied electromagnetic research. Recently they focused their research on metamaterial directive antenna. In this way, they developed a DC voltage control beam steering metamaterial antenna. The main function of this antenna is to tune the beam azimuth by DC voltage. Like phased array antenna, the antenna consists of a voltage-controlled metamaterial slab (beam steering antenna) of 36 phase shifters and a patch antenna. By applying a specific voltage on a phase shifter, a corresponding phase will result. The final direction of the antenna is determined by the 36 phases together.

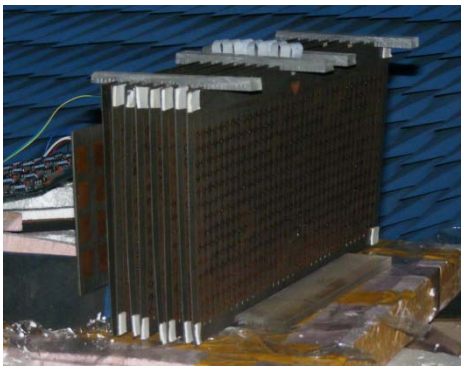


Figure 1 : Voltage control beam steering antenna board

The final aim is to control the applied voltage on the beam steering antenna by a computer, and thereby be able to control the direction of the whole antenna in real-time. In order to realize it, some intermediary interface shall process the incoming computer information and apply the right voltage on each phase shifter.

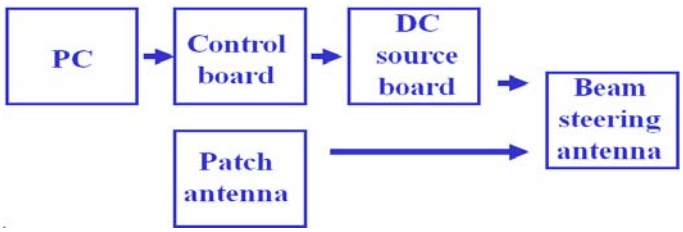


Figure 2 : Solution block schema

Our solution is to have a first control system (Control board) to fulfill the communication between the computer (PC) and a power source system (DC source board). The DC source board shall perform the digital to analog conversion of the received user information in order to provide and keep the correct voltage on each phase shifter of the beam steering antenna. By placing the patch antenna behind the regulated beam steering antenna, the DC voltage control beam steering metamaterial antenna is completed.

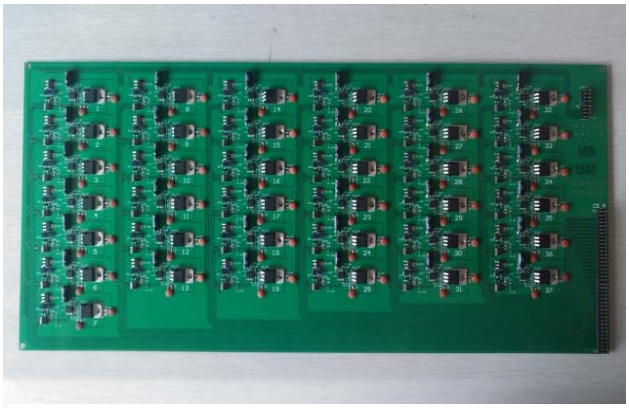


Figure 3 : DC source board

The DC source board has already been done. To provide the specific voltage for each phase shifter, thirty-seven digital-to-analog converters are used. The chosen communication interface for the DACs is the SPI protocol, a common and easy to use serial communication interface. Each DAC is able to receive digital information through the SPI interface, converts it into analog signal, which reflects the digital information, and keep the result on the output until new digital information is received. Each DAC possesses an amplifier to increase the output voltage into a range of 2-10V approximately.

As mentioned above, an additional interface is needed to fulfill the communication between the computer and the DC source board. Due to the communication interfaces are different, the control system shall work as protocol translator between USB and SPI in order to transmit the digital information coming from the computer toward the DC source board.

This paper present the realization of the control system, a communication interface between a computer and thirty-seven serial interfaced (SPI) digital-to-analog converters (DACs) incorporate in the DC source board.

2 Objectives

The existing DC source board is only able to communicate through SPI interfaces. Therefore, in order to send information to the DACs from a computer, a translation interface is needed to handle the computer data and send it toward the DACs.

The final objective consists of a user cable to enter a desired direction angle into a graphical interface, on a computer, and control the antenna's direction. Due to the relation between applied voltage, phase shifter and final direction isn't known yet, some experimental tests are needed. In order to realize these tests, the user shall also be able to control the output voltage of each DAC in order to regulate each single phase shifter of the voltage –controlled board (beam steering antenna) and thereby determine the right relation between voltage, phase and direction. Once the relation established, the user should only enter the angle and each single DAC voltage shall be calculate by the MCU incorporate in the control system.

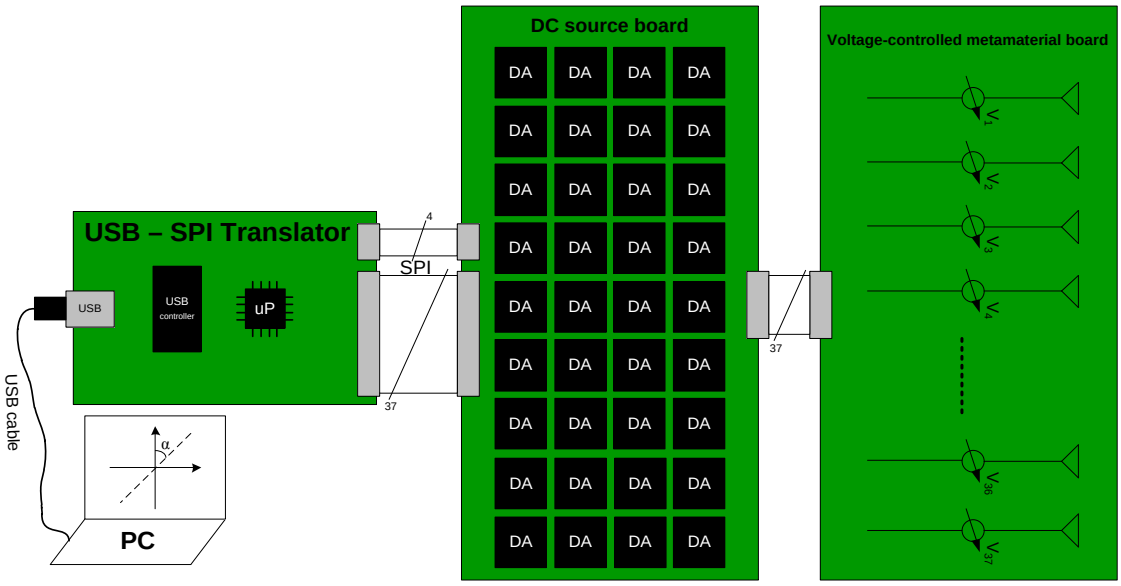


Figure 4 : General view of the system

The main purpose of the project is to realize a USB-SPI translator system which provides both hardware connection and transparent data transmission functions. In order to accomplish it, several tasks are required:

- First, a small hardware is to be designed, fabricated and debugged which realize the electrical connection between a standard USB port and multiple standard SPI interfaces.
- Once the hardware finished, a small firmware for the data unit processing (MCU) connected with a USB controller has to be written. The system shall work as translator between USB and SPI protocols.
- Write a graphical interface for the user, which realizes the bidirectional communication with the hardware.

3 Requirements

In projects it's essential to clearly and completely define the functions and duties of the product. The system has to meet certain requirements; some of them are defined by the user [1], others are necessary to obtain a well working system.

The USB-SPI Translator system shall:

Functional specifications

- process data between a USB interface and 37 SPI interfaces
- update the DACs output voltage on the DC source board
- implement a FT245R USB controller and a ATmega88 microcontroller which are communicating in parallel operation

Interface specifications

- have a maximal size of 16.5mm by 3.5mm and shall be able to be fixed to the digital-to-analog board
- be a low power consumption system
- provide a SPI master interface able to communicate with 37 SPI slave devices

GUI specifications

- allow the user to choose between different data transmission types
- allow the user to type in the desired information to be transmit
- transmit the information typed in by the user by using the provided FTDI driver
- receive information by using the provided FTDI driver
- display the received information

Convenient specifications

- provide a battery able to supply the data processing unit
- process feedback information of the DACs output voltage

Further, some additional specifications might be defined in order to obtain a complete well working product.

4 Global System Architecture

As result of the analysis of the objectives and the requirements, a first block diagram describing the global system architecture, is shown in Figure 5. A more specific and detailed system architecture is depicted at the end of section 5 *Hardware*.

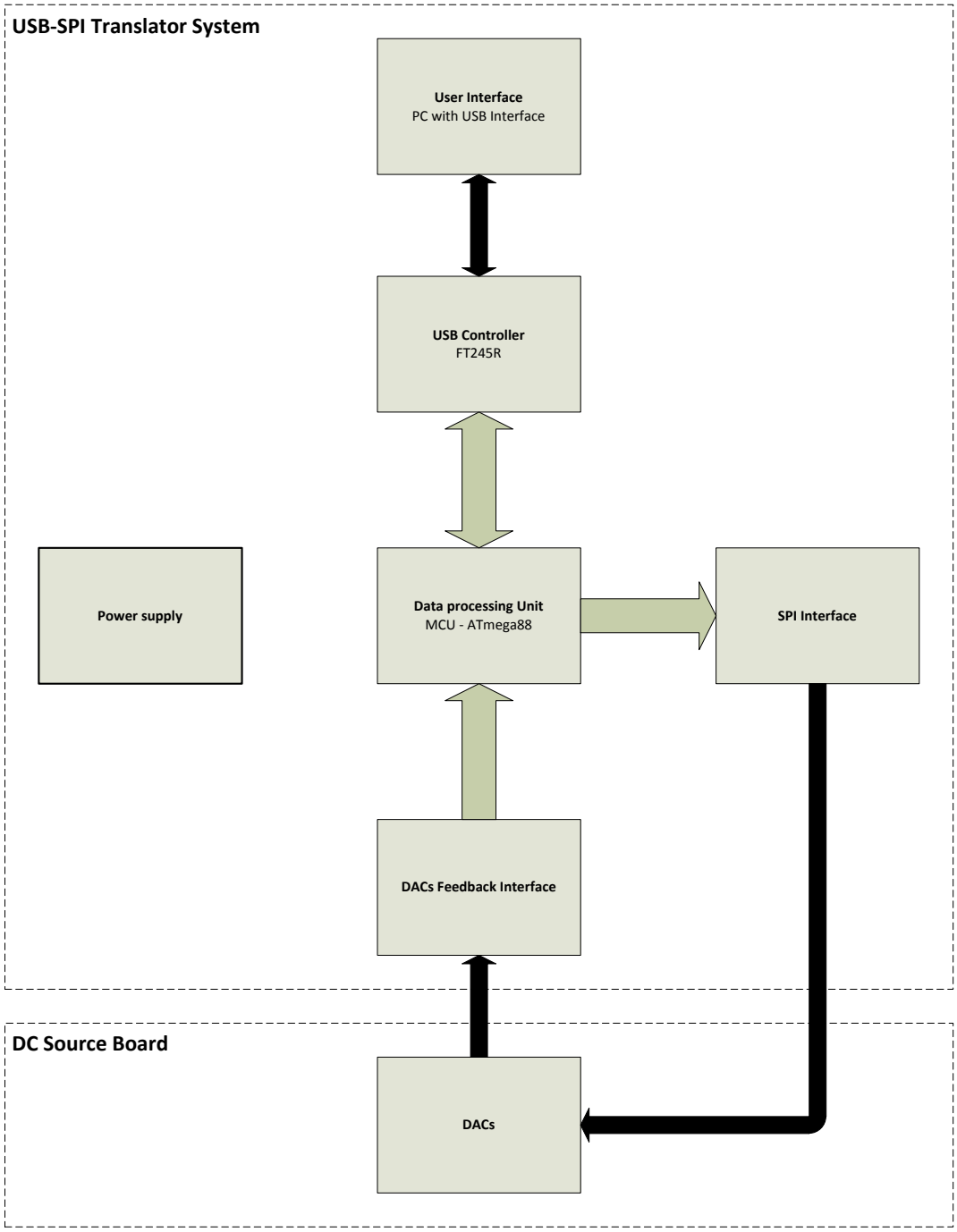


Figure 5 : Global System Architecture

5 Hardware

In this section the hardware of the USB-SPI Translator system is discussed. Each function is described and the selection of the components is explained. For the experimental version, most of the components used are chosen from the lab if available and if the requirements are met, for convenience. If the experiment work out well the final version can integrate more specific devices as mentioned in this paper.

This discussion allows us to represent the USB-SPI Translator system in a more detailed system architecture (see section 5.5 *Detailed System Architecture*).

The different schematics resulting from the discussion are included in Appendix sections B *Schematic*. Also all the components used are listed in Appendix sections D *Components list*.

5.1 Power

5.1.1 Power Source

For embedded systems, in which the mobility and the self-sufficiency are important, it's very useful to use a battery. On the contrary, if the system stay at the same place and the maintenance shall be very seldom, it's a better way to use an external power supply.

In this application the system doesn't need especially to be self-powered, but due to the USB-SPI Translator system is in charge for carrying information between equipment, a self-powered system can be used during power cuts in order to save the information. In this way, the system shall be able to switch the power source from external power link to a battery able to supply the data processing unit of the system, when the external power source is no longer available.

In order to fulfill this function, the system shall provide a DC connector with both signals, 5[V] and GND, and a battery able to supply the system, or at least the data processing unit.

External link

In order to supply the whole system by external power, one standard DC connector is needed. As external supplier, the digital-to-analog converter board is able to provide 5[V] power which is perfect. A standard ISP 2 pins connector is used to draw the power from the external supply to the USB-SPI Translator system.

Power pack

To choose a battery for the system, some calculation about the needed battery capacity and its life time have to be done.

First, a table with the different potential components is defined. With the help of the given manufacturer datasheets, each component consumption, for idle and active states, is defined and the approximate system consumption can be calculated. The results are shown in Figure 6.

	I min [mA]	I max [mA]
MCU [2]	0.25	3
CPLD [3]	0	50
USB Controller [4]	0	25
Step-up [5]	0.1	5
Voltage regulator	0	10
LEDs	20	20
Total	20.35	113

Battery capacity [mAh]	Min life [h]	Max life [h]
40	1.97	0.35
100	4.91	0.88
200	9.83	1.77
250	12.29	2.21
500	24.57	4.42
700	34.40	6.19
Theoretical		

Figure 6 : Total system consumption and life time calculations

Comment:

All the calculations are theoretical and thereby the obtained results might differ with the reality. This should be taken into consideration when choosing the right battery for the system.

Once the system consumption known and the life time defined, the battery capacity can be calculate with the formula as follow:

$$Capacity\ [mA\hbar] = Total\ system\ consumption * life\ time \quad (1)$$

A comparative table, Figure 7, showing different batteries gives an idea of what kind of battery the system needs. It allows us to understand the relation between the size of the battery and the capacity of it. The table points out clearly that the capacity depends strongly on the size.

Fabricant	Model	Technology	Capacity [mAh]	Voltage [V]	Size [mm]	Connection	Item	Total Voltage [V]
VARTA	55615604940	NiMH	150	4.8	23x15x14	PCB pin	1	4.8
VARTA	55625603059	NiMH	250	3.6	25x20x26	PCB pin	1	3.6
VARTA	55625602059	NiMH	250	2.4	25x20x27	PCB pin	2	4.8
VARTA	55750504012	NiMH	500	4.8	70x50x9	wire	1	4.8
Pololu	1005	NiMH	700	4.8	46x41x11	wire	1	4.8
VARTA	56445201012	Li-Ion	595	3.7	42x34x5	wire	1	3.7
VARTA	56427201012	Li-Ion	1400	4.2	60x40x5	wire	1	4.2
VARTA	56622201013	Li-Ion	2200	3.7	65x18	wire	1	3.7
ENIX ENERGIES	800042	Li-Ion	2600	3.75	55x45x18	wire	1	3.75
DMS Technologies	7140-0085	NiCd	700	4.8	50x50x15	wire	1	4.8
Panasonic	AAA ZR03/2BP	Nickel Ox.	850	1.5	45x10	support	3	4.5
VARTA	56422302016	Lithium	2600	3.7	65x35x10	wire	1	3.7

Figure 7 : Battery comparative array

As the size of the hardware is limited, the size of the battery is determinant. Another significant point is the technology used. By using Li-Ion technology, the charge of the battery should be accurate and a battery controller is needed in order to regulate the charge. On the other hand, NiMH batteries can be

easily charged with small current flow without external regulation. The second choice is more convenient for the system, due to the gain of size is significant.

As result of the formula (1), the capacity of the battery should be between 250mAh and 700mAh. As well, the table above contains a battery that meets the different discussed requirements. The small size of the selected battery was a major feature for the choice.

Fabricant	Model	Technology	Capacity [mAh]	Voltage [V]	Size [mm]	Connection	Item	Total Voltage [V]
VARTA	55625603059	NiMH	250	3.6	25x20x26	PCB pin	1	3.6

The battery chosen for the experimental version differs with the selected one[1]; the characteristics are shown below in Figure 8.

Fabricant	Model	Technology	Capacity [mAh]	Voltage [V]	Size [mm]	Connection	Item	Total Voltage [V]
SZL		NiMH	40	3.6	17x13x16	PCB pin	1	3.6

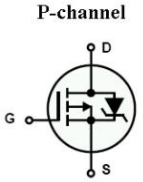
Figure 8: Used battery

5.1.2 Power Management

The system has two different potential power sources, and especially one of these power sources is a battery that needs to be managed. Follow the power management circuit, which fulfill the power source selection and the battery management, is described.

Battery control

As the battery is normally always connected to the system, a P-MOSFET transistor (U1A) is used to control the battery utilization. MOSFET are voltage-driven transistors. The theoretical relation that controls the P-MOSFET conductibility is as follow:



$$V_{GS} = V_{Gind} - V_{Source} \leq 0[V] => Drive!$$
$$V_{GS} = V_{Grind} - V_{Source} > 0[V] => Blocked! \quad (2)$$

Figure 9 shows the use of the transistor (U1A) as switch. The battery is connected to the source of the P-MOSFET and the external power link (Vdc) is connected to the grind in order to control the transistor. When the external power is available (5V), the P-MOSFET is open and no current is drawn from the battery. On the contrary, if no external power is available (0V), the P-MOSFET drives and the battery will supply the system.

[1] For the experimental version a smaller battery available in the lab has been chosen for convenience.

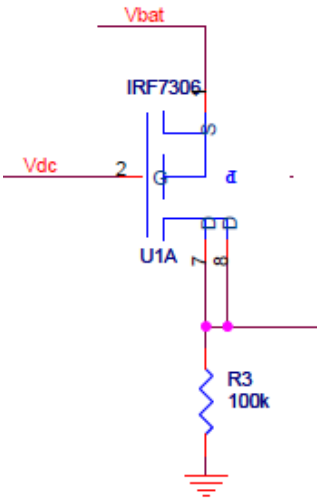


Figure 9 : Battery control

Step-up

When the battery is being used the voltage of this one drop. In order to have a constant output voltage of the battery power source when it's being used, a voltage converter IC chip is used to step up the voltage to a constant 5[V].

The *ON Semiconductor NCP140 [5]* step-up DC/DC converter is chosen for this application[2]. The *NCP1410* device is a boost voltage switching converter IC specially designed for battery operated hand-held electronic. The operating input voltage range of the IC, for a 5[V] output, is between 1.8[V] and 5[V] and the output current drawn from the battery can be up to 200mA at 2.2V input voltage.

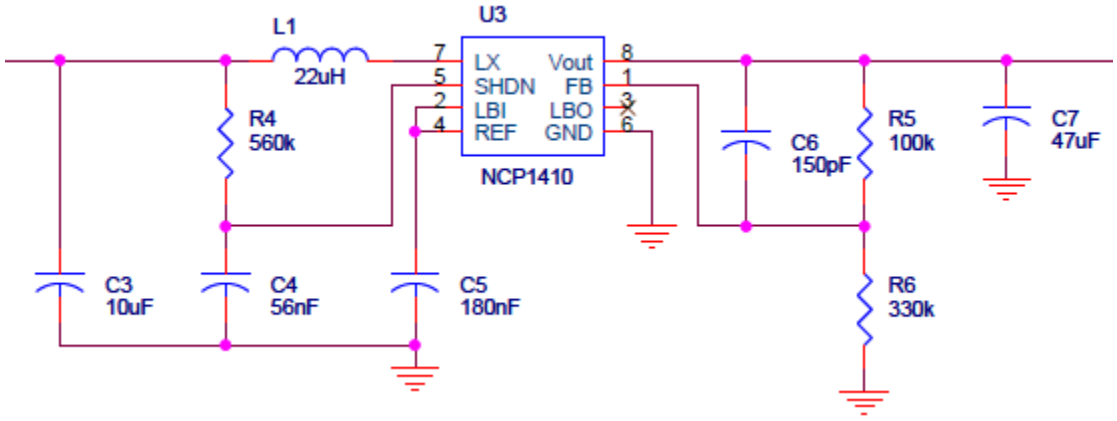


Figure 10 : Step-up 5[V]

[2] The step-up was chosen because it was available in the lab and met the requirement.

The output voltage of the converter is determined by the external feedback network comprised of R5 and R6 (refer to Figure 10). Below is described the calculation for a 5[V] output with the given relationship:

$$Vout = Vref\left(1 + \frac{R5}{R6}\right) = 5[V] \tag{3}$$

Select R5 = 100KΩ

$$R6 = R5\left(\frac{Vout}{Vref} - 1\right) = 100K\left(\frac{5}{1.19} - 1\right) = 333K\Omega$$

The besides used components for a well working step-up are chosen according to the datasheet given by the manufacturer [5].

Power selector

Due to the system can be supplied by two different power sources, some electronic is used to select the power source which has to supply the system. If the external power source is available, the system shall be supplied by this one and not use the battery.

A P-MOSFET transistor (U1B) is used to select the power source (see Figure 11). For the conductibility of the P-MOSFET, refer to the relation (2) on page 13. The external power source is connected to the drain of the P-MOSFET and the step-up output (battery power source) to the grind. The source pin of the P-MOSFET drives the selected power source toward the system.

When external power is available the first P-MOSFET transistor (U1A), which controls the battery utilization, doesn't drive and the step-up circuit output is null (0[V]). With the grind voltage low, null, the second P-MOSFET transistor (U1B) drives and the external power source supplies the system.
On the other hand, if the external source isn't available the first P-MOSFET (U1A) drives the battery current through the step-up which apply 5[V] on the grind. Thus, the second P-MOSFET (U1B) doesn't drives and the battery supplies the system through a standard diode. The diode is used to avoid a feedback voltage on the step-up output when the external source supplies the system.

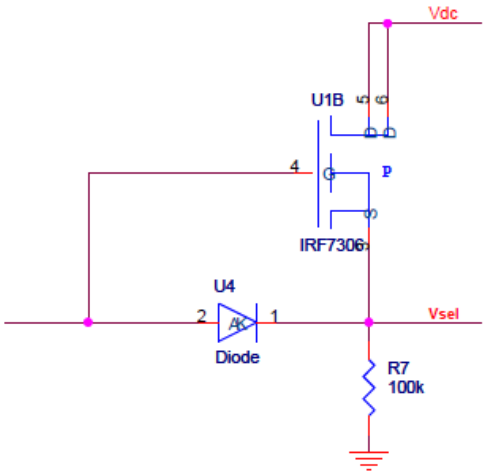


Figure 11 : Power selector

Power management simulation

A simulation of the power management has been realized with the *OrCAD* software *PSpice*. For the simulation the schematic is simplified as shown in Figure 12.

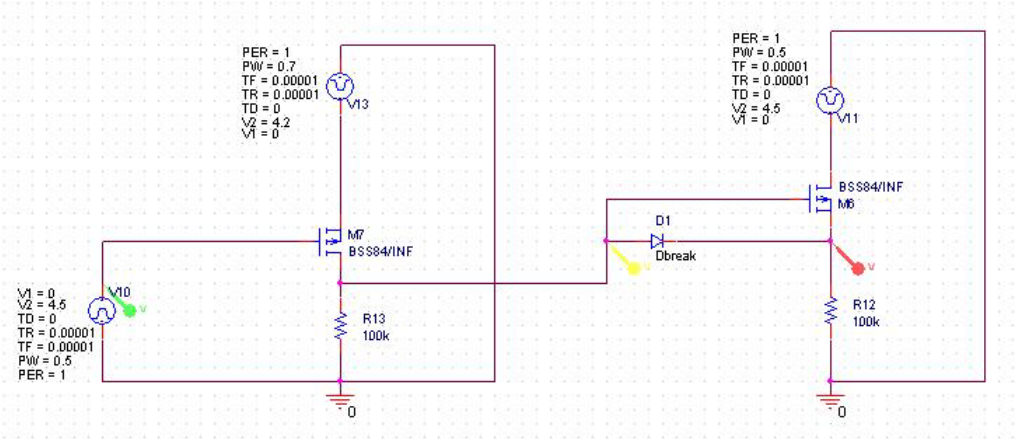


Figure 12 : Power management simulation schematic

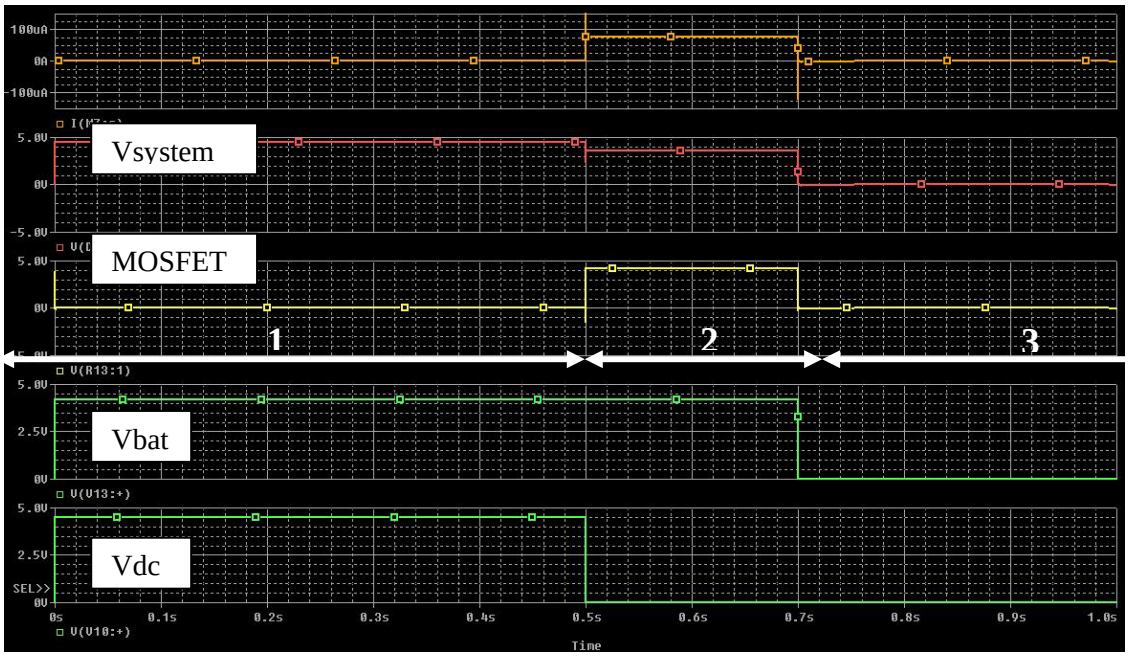


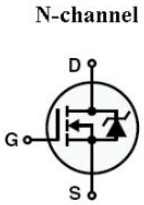
Figure 13 : Power management simulation result

If external supply (*Vdc*) is available, the simulation shows that the first MOSFET (yellow signal) doesn't drives. As the first MOSFET monitor the second MOSFET, the external power source supply the system (red signal) (1). When the external source is no longer available, the first MOSFET drives and consequently block the second MOSFET. The battery supplies the system through the diode (2). The output voltage (*Vsysem*) is reduced due to the power drop on the diode. If no power sources are available, the output voltage is null (3).

5.1.3 Battery recharge management

In order to avoid the necessity to recharge the integrated battery by another special system, the USB-SPI Translator system shall perform the recharge of the battery.

The battery source should be connected to an analog pin from MCU in order to convert the battery level with the built in analog-to-digital converter. The obtained digital result is used by the MCU to control the charging of the battery. The battery should be recharged only if the voltage level is under a specified low threshold and should stop charging when the voltage reached the specified high threshold. The MCU controls the charge of the battery by controlling the conductibility of an N-MOSFET (U2A in Figure 14) with the signal "charge". The theoretical relation that controls the N-MOSFET conductibility is as follows:



$$V_{GS} = V_{Gind} - V_{Source} = 0[V] => Open!$$
$$V_{GS} = V_{Grind} - V_{Source} > 0[V] => Drive! \quad (4)$$

The N-MOSFET drives when the "charge" signal on the grind is high and will consequently connect the ground to the diode. If the control signal is low, the N-MOSFET is open and the external source is connected to the diode.

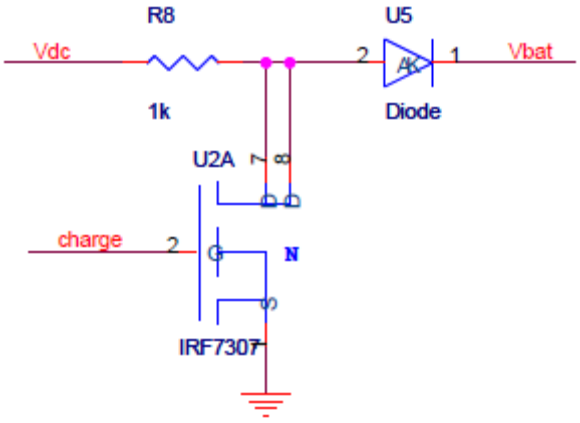


Figure 14 : Battery charger

The purpose of the diode[3] is to avoid that the N-MOSFET (U2A) draws current from the battery when the external source isn't available. The diode only drives if the voltage on the anode side, external power source, is higher than the voltage on the cathode side, battery side. The current drawn by the battery is exponential of the voltage different between anode and cathode as shown in Figure 15.

[3] The diodes are standard diode chosen from the lab.

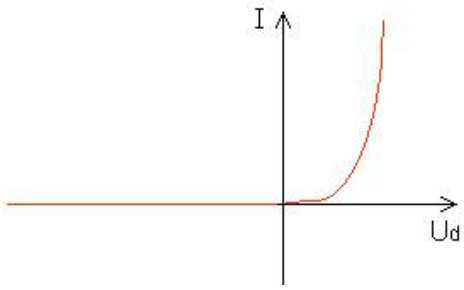


Figure 15 : Diode characteristic curve

The diode characteristic curve above shows clearly that more the battery is charged, less current is driven by the diode due to the voltage different between anode and cathode become smaller. This characteristic is interesting by the fact that it is better for the battery to reduce the charging current above 80% of charge capacity. When the external power source isn't available or the signal "charge" is high (no charging), the voltage different between anode and cathode is negative, thus no current is driven by the diode and the battery is protected.

The external source is directly connected to the diode as shown in Figure 14. The current provided by the external source is unknown, thereby a resistance (R8) is used to decrease the charging current. A small charging current scale is determined, after what the resistant can be calculated as follows:

Select I_{charge} = 5mA

$$R8 = \frac{V_{ext}}{I_{charge}} = \frac{5}{0.005} = 1k\Omega \quad (5)$$

5.1.4 Switch ON/OFF

The user shall be able to turn on and off the system by using a push button. When the system is shutdown, the minimal electronic shall be supplied in order to avoid a waste of current, especially when the battery is supplying the system.

When the USB-SPI Translator system is switched off, a minimal electronic should be supplied only to allow the user to switch on the whole system. To control the supply of the system behind the switch ON/OFF circuit, a P-MOSFET transistor (U7B in Figure 17) is used. For the conductibility of the P-MOSFET, refer to the relation (2) page 13.

As shown in Figure 17, the grind of the P-MOSFET controls the conductibility of the transistor, so when the system is switched on, the grind should be low, null. Like this the transistor drives and the whole system is supplied by the selected power source. If the system is turned off, the grind should be high, in this case the transistor becomes open and by consequent the system is turned-off.

In order to control the P-MOSFET transistor, a RS-Flip-flop is used. A NAND RS-Flip-flop produces a low level on the output by applying a low level on the Set input. By applying a low level on the Reset input, a high level result on the output. If both inputs are high level, the output is kept unchanged. The logical connection and the true table of the NAND RS flip flop are shown in Figure 16.

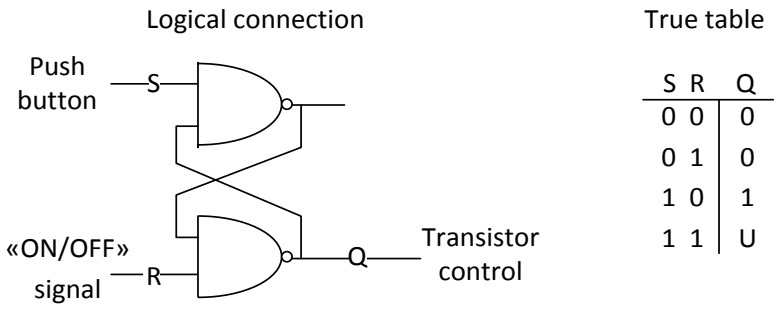


Figure 16 : RS Flip flop

The *CD4011B* chip from *Fairchild* [6] manufacturer is chosen[4] to fulfill the NAND RS flip flop. The device is a CMOS technology integrated circuits consisting of four 2-Input NAND gates.

As mentioned above, the user should be able to turn on the system by using a push button (SW_ON).As shown in Figure 17, by pushing the button, the user connects the ground to the Set input of the RS flip flop. As consequent, the RS flip flop output is pulled down and the N-MOSFET transistor drives the selected power source (Vsel) forward the system. A pull-up resistance on each input keeps the output state unchanged and thereby the system stays supplied.

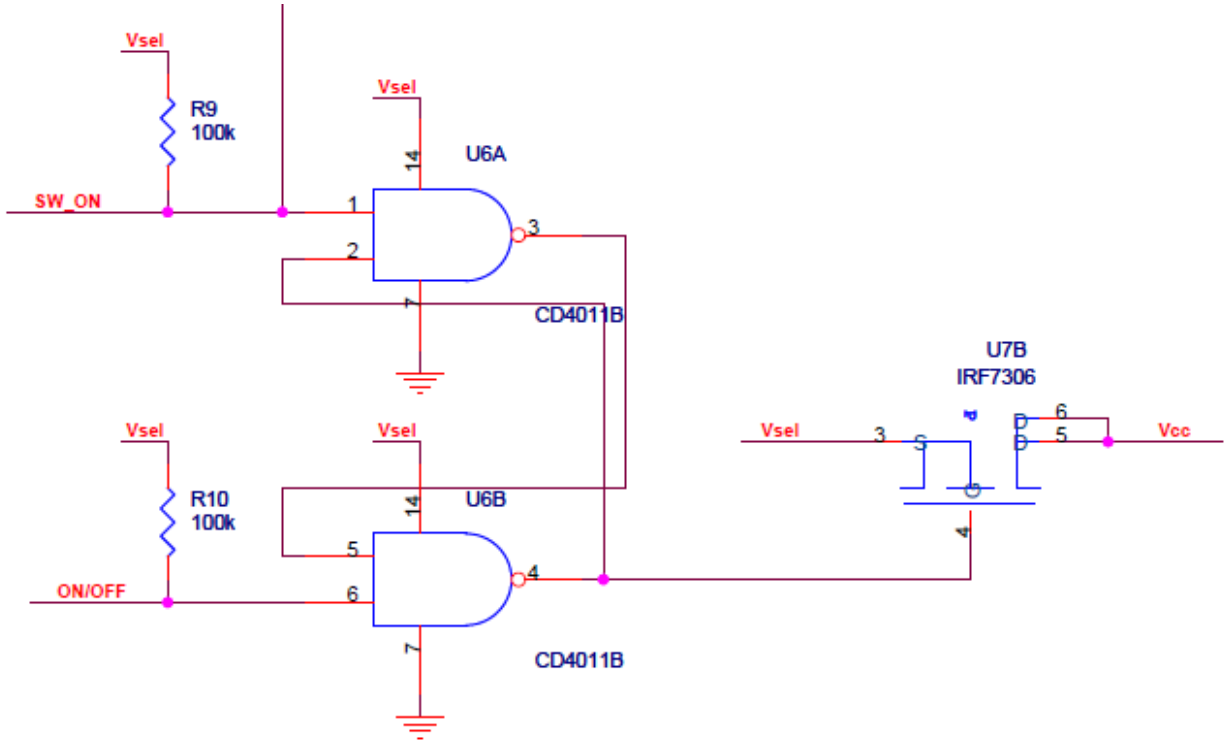


Figure 17 : Switch ON/OFF

[4] The CD4011B chip was chosen for its availability in the lab.

The push button should be used for the switch on and the shutdown for a well-working system. In order to fulfill this requirement, the push button is connected through an N-MOSFET transistor (U7A) working as interrupter, to the MCU (Figure 18). The pull-up resistance (R9) on the set input of the RS flips flop keeps the transistor open. When the user push the button, the grind of the P-MOSFET is connected to the ground and allows the transistor to drive. It allows the MCU to be aware of the push button state. The microcontroller shall pull down the “ON/OFF” external signal in order to shut down the system, when the user push the button more than a defined time. The “ON/OFF” signal is connected to the reset input of the RS flip flop, applying a low level on the reset input will produce a high level on the output of the RS flip flop, and by the way shut the system down.

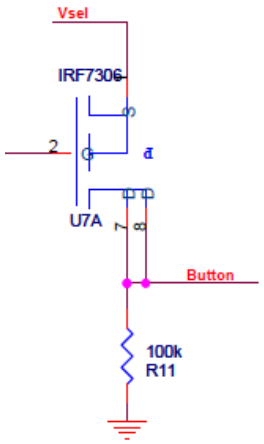


Figure 18 : MCU button

5.1.5 Provided Power Levels

The USB-SPI Translator system use different voltage level for different components and therefor the system shall transform the source power into the different needed power level.

The provided voltage level by the selected source power is 5[V], voltage regulators are used to regulate the voltage level. For each voltage level, a specific voltage regulator is chosen.

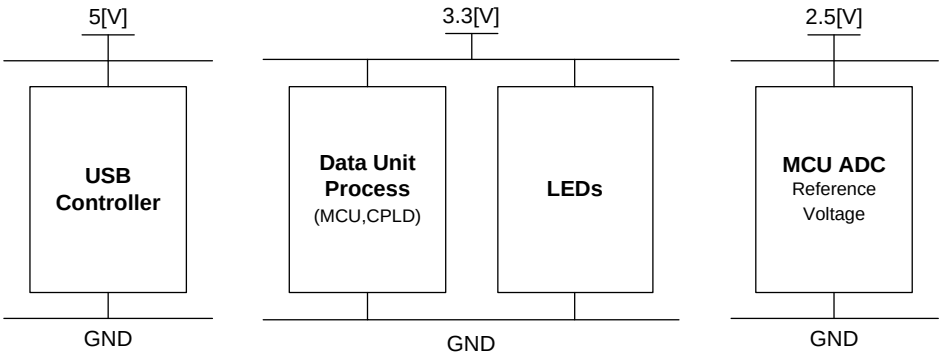


Figure 19 : Power levels

Figure 19 shows the different voltage level used by the different functionalities. It results that the system should integrate two voltage regulators.

Only the USB controller is supplied with the full power level. The reason is that the minimal well-working voltage limit given by the manufacturer for the *FT245R* [4] device is 4[V].

In order to have a low power consumption system, a 3.3[V] voltage level is chosen for the different data processing unit, the *ATmega88* [2] microcontroller and the *XC95144XL* CPLD [3] (refer to section *5.3 Chips selection*). The *MICREL MIC5205-3.3BM* [7] voltage regulator from manufacturer is chosen[5] in order to provide a 3.3[V] power level.

The digital-to-analog converters used on the DACs board are using a reference voltage level of 2.5V. Thereby the analog-to-digital converter integrate in the MCU should have the same reference voltage level. This way the feedback information can be accurate. The same voltage reference chip as used by the DACs board is chosen, the *BB TI manufacturer REF3025* [8] voltage reference chip.

5.2 Data Processing

To handle all the outgoing and incoming signals, the USB-SPI Translator system needs a processing unit to manage it. The main task of the processing unit is to translate communication protocols for bidirectional data transmission between standard USB interface and standard SPI interface.

5.2.1 USB

The main data processing unit is the microcontroller, but in order to successfully communicate with a computer through USB protocol, a USB controller is used. The controller used shall work as translator between a standard USB communication link and a FIFO communication interface able to communicate with the MCU by parallel operations.

The *FTDI FT245R* [3] USB controller chip chosen (refer to section 3 Functional specification) is a USB to parallel FIFO interface for bidirectional data transfer by rates up to 1Mbyte/second. In Figure 20 the USB controller is designed according to the given datasheet [3].

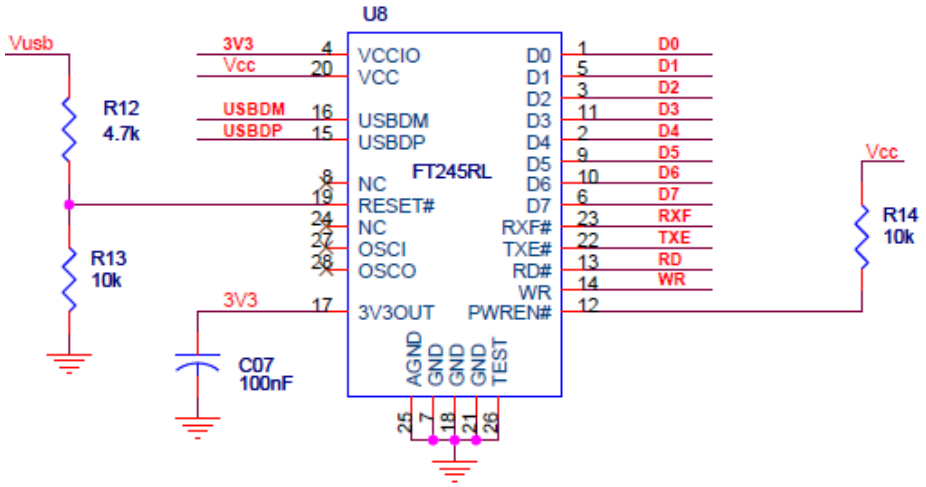


Figure 20 : USB Controller

[5] The MIC5205-3.3BM chip was chosen for its availability in the lab and its already use in the DC source board

Power configuration

The *FT245R* chip supports bus powered or self-powered configurations. Because we have a separate power supply, the chip is self-powered. As the USB controller device is self-powered, it shouldn't draw current down the USB bus when the USB host is powered down. In order to comply with this requirement above, the bus power (Vusb) is used to control the RESET # pin of the *FT245R* device as shown in Figure 20. Like this, when the USB host is powered the RESET# signal is high and the device is functional. When the USB host is shut down, the signal on RESET# is low and the device is turned off until the host switches on again.

5.2.2 MCU

The microcontroller is the central control unit and thereby is connected with the whole system, by signals and data lines. The chosen microcontroller is the *ATmega88* from *Atmel* [2] (refer to section 3 Functional specification). The ATmega88 device is a low power CMOS 8-bit microcontroller based on AVR CPU architecture. The hardware of the used MCU features (I/O, SPI, A/D Converter) are described in this section. Figure 21 shows the MCU pin connections.

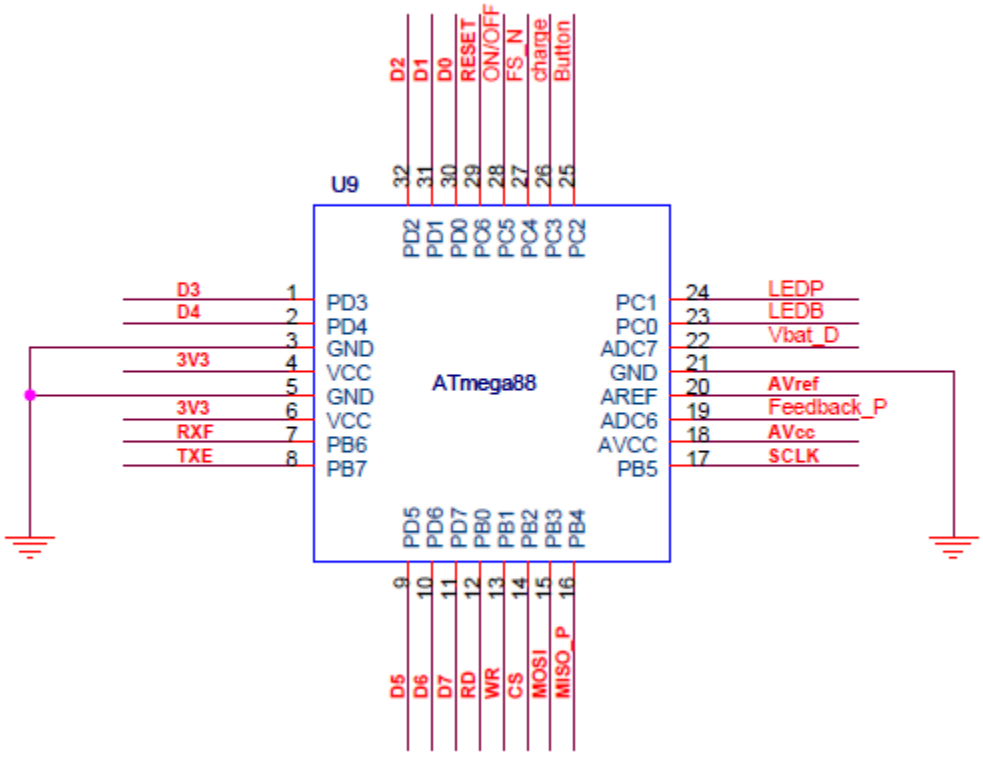


Figure 21 : MCU pin connection

USB Controller to MCU connection

The main task of the MCU is to process the data between a USB host (Computer) and 37 SPI interfaces (DACs). As described above in section *5.2.1 USB*, an intermediary device is used for the communication with the computer.

As the USB controller communication interface with the microcontroller is an 8-bits parallel FIFO interface, two 8-bits ports from MCU are used for the bidirectional data transfers with the intermediary device. One 8-bits port, the PORTD (PD) is used to transfer the 8-bits data. The another 8-bits port, PORTB (PB) from MCU, use four bits to monitor the RXF# (PB6) and TXE# (PB7) status bits and generate the RD# (PB0) and WR (PB1) strobe signals to the device when required. The RXF# and RD# signal are used to read the data on the device. The TXE# and WR signals are used to write the data into the USB controller.

I/O Signals

Like mentioned before, the MCU is the central control unit, therefor one of its duty is to control the different external signals. Some of these signal are used to control the system, others are used to control external status information for the user.

Light emitting diodes (LED) are used as status information. One LED shall inform the user of the working state of the system, ON/OFF. Another LED shall inform the user of a low battery level, and if external power source available, battery recharging status.

SPI interface

The chosen MCU provide an SPI interface. This feature is used by the system to communicate with the digital-to-analog converters on the DC source board. The SPI interface provided by the USB-SPI Translator board has to work as master device and be able to communicate with 37 SPI slave interfaces.

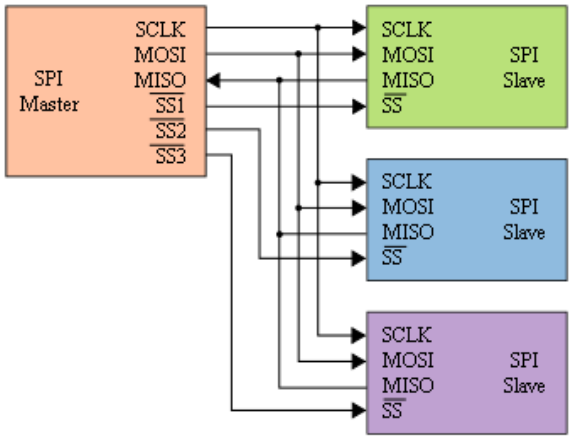


Figure 22 : SPI link for multiple slave

Figure 22 shows the connection between one master SPI interface and several slave SPI interfaces. The data links stay the same for each slave devices. A slave select signal is used to enable the slave device that has to exchange the data information with the master device. Due to the DACs used are 10bits devices, two SPI transmissions are necessary to update a DAC. In order to synchronize the data transfer a additional signal (FS_N) is used.

Because the chosen MCU has not enough I/O pins to provide 37 slaves select signals, a sub-system is used to perform the slave devices selection. This slave selection sub-system is described in section *5.3 Chips selection*.

Analog-to-digital converter

The chosen microcontroller integrates a 10-bit analog-to-digital converter (ADC), which means analog signal are able to be process by the MCU. The built in ADC is used to convert the feedback information of the digital-to-analog converter output. After data processing by the MCU, the user can be aware of the different DAC voltage level in real-time. Another use of the provided ADC is to convert the battery voltage level in order to control its charge.

In order to have an accuracy A/D converter, the analog voltage supply for the ADC (AVcc pin) should be connected to the digital supply voltage (3V3) via an LC filter as shown in Figure 23.

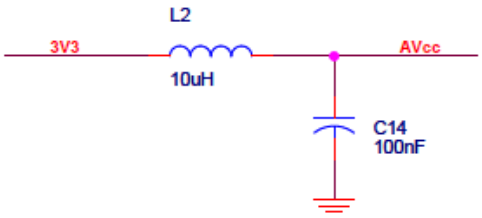


Figure 23 : LC filter

The voltage reference used by the digital-to-analog converter on the DC source board is 2.5[V]. As the conversion result depends highly on the voltage reference used, the same reference voltage should be used by the built in ADC as the DC source board. Figure 24 shows the voltage regulator used for a precise voltage reference of 2.5[V]. The device used is the same used by the DACs board (refer to section 5.1.4 Power levels).

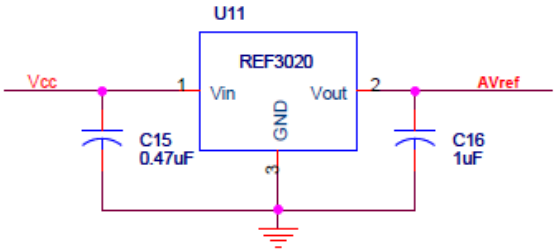


Figure 24 : 2.5[V] Voltage reference

The *ATmega88* microcontroller provides two permanent analog inputs. They are used for the DACs feedback (ADC6) and the battery feedback (ADC7). Due to the microcontroller can't provide 37 analog inputs for every DACs output, a sub-system is used to select the DAC which has to be converted. The DAC feedback sub-system is described in section *5.4 Feedback channel selection*.

Because 2.5[V] is used as reference voltage, a voltage divider is used for the battery signal in order to match the highest battery output voltage with the reference voltage. This is necessary because the converting input voltage range is between 0[V] and Vref.

$$Vout = Vref = Vbat_{max} * \frac{R16}{R16 + R15} = 2.5[V]$$

By selecting R15=**100**[kΩ], R16 resulting is **200**[kΩ].

MCU programming interface

To be able to write the firmware into the microcontroller, a programming interface is needed. A multi device programming interface, called ISPExpert, is used as programming device for the MCU. The ISPExpert device is able to work with Joint Test Action Group (JTAG) and In-System Programming (ISP) programming protocols.

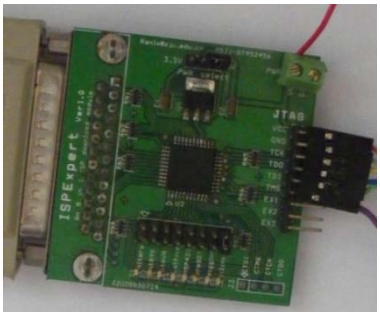


Figure 25 : Programming device

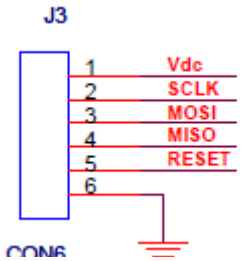


Figure 26 : Programming connector

The second choice, ISP protocol, use the SPI interface to write into the target device, for that reason this option is chosen in order to avoid waste of pin uses, as the MCU I/O pins are limited. Figure 26 shows the electrical connection for the programming connector.

5.3 Inputs protection

The USB-SPI Translator system communicates with external systems and is able to receive information from them. For this reason a protection for the MCU should be implemented. A zener diode with a serial resistance is used as protection circuit against high voltage signal on the MCU.

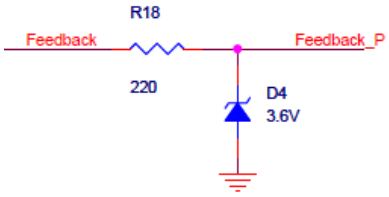


Figure 27 : Input protection circuit

As shown in Figure 27, each external input signal is connected in series to a resistance and to a zener diode in parallel. The breakdown voltage for the zener diode is chosen according the highest potential signal voltage level. When the analog signal is higher than the breakdown voltage of the zener diode, the diode will drive and the MCU pin will see 3.6[V]. The excess of voltage is absorbed by the resistance. Like this the MCU is protected from external high voltage level. The formula (6) below shows the relation for the serial resistance (R18):

$$\frac{Ue_{max}-Uz}{Iz_{max}} < Rs \qquad (6)$$

According to the datasheet of the zener diode [9], Izmax is calculated as follow:

Izmax = Pmax/Uz = 139[mA]. By using the obtained result in the formula (6), Rs can be determined (Uemax = 25[V], Uz = 3.6[V]). The resistant value should be above 157[Ω], therefore the selected value for Rs (R18) is **200**[Ω].

5.4 Chips selection

In order to send new digital information to the digital-to-analog converters, the CS pin of the DAC chip needs to be pulled down firstly. The MCU already chosen (ATmega88) own 23 programmable I/O pin and actually the system needs 37 slave select as mention above in section *5.2 2 MCU (SPI interface)*. Therefore a specific sub-system, described in this sub-section, shall manage the chips selection.

Several solutions could be used to perform the chips selection. In order to choose the best solution for the application, an analysis about different ideas is depicted below.

A first array including four potential solutions shows in Figure 28 the difference between the ideas. After what Figure 29 show the advantages and disadvantages for each idea.

Idea	Workable	HW	SW difficult	Consumption
Bigger MCU	YES	Little size extension	output selection	75uA < I < 400uA
Second MCU	YES	Double size extension	CS divided selection	500uA
MCU-CPLD	YES	Extra chip extension	MCU-CPLD communication	< 50mA
De-Multiplexer	YES	Some extra chips extension	address selection	< 300uA

Figure 28 : Ideas comparative array

	Advantage	Disadvantage
Bigger MCU	• Only one chip used • No synchronization with another chip • Low power • Easy connecting link	• Use of unknown MCU by the lab • Specification requires ATmega88
Second MCU	• Multitask	• Data sharing • Divided chip selection • Synchronization between both MCU
MCU – FPGA	• External chip that perform the chip selection, meanwhile the MCU can perform others task • Use of SPI interface for communication and thereby no use of supplementary pin	• Synchronization between MCU and FPGA • Extra debug interface used
De-multiplexer	• Few pins used	• Some extra chips used • Complicated connecting link

Figure 29 : Advantage / Disadvantage table

Although the analysis shows clearly that using a bigger MCU for the application is the best solution, the specification requires the use of the ATmega88 MCU. Consequently the second best solution, which is

the use of a CPLD for the chips selection, is kept. The chosen CPLD for the application is the *XC95144XL* device from *Xilinx*[6] [3].

5.4.1 CPLD

To use a CPLD for the chips selection, the MCU and the CPLD has to communicate together. SPI protocol is used as communication interface between the MCU and the CPLD device. Figure 30 shows the SPI data signals used for the communication.

Figure 30 : Data transfer signals

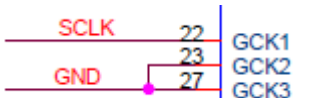


Figure 31 : CPLD clock signal

The CPLD need an external clock to work. The SPI clock from MCU is used as clock signal for the device. As shown in Figure 31 only one clock reference is used. In this way, the CPLD is at any time synchronous to the MCU and the communication become easier.

A push button is added to the system for the CPLD. The button pulls up the general set/reset (GSR) pin when it's pushed, in this way the button can be used as reset button for the CPLD.

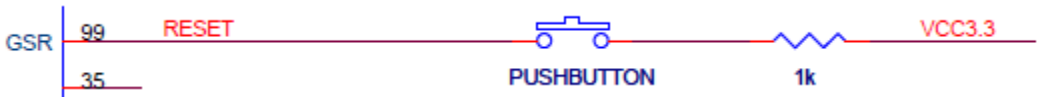


Figure 32 : CPLD push button

Due to the CPLD is used to select the DACs, each DAC chip selection signal has to be connected to the CPLD as output. In order to enable the DAC read the new digital information to convert, the corresponding CS_N pin is pulled down.

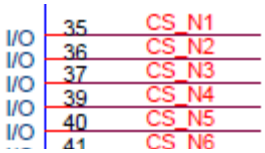


Figure 33 : Chips selection pin (sample)

5.5 Feedback channel selection

As the USB-SPI Translator system conveys digital information toward the digital-to analog converters, it might be interesting to have a feedback of each DAC's output voltage.

The MCU shall read the output of the DACs, digitalize it with its integrated analog-to-digital converter and then send the information back to the computer. As mentioned above, a sub-system is needed to select and thereby connect the DAC output signal to the analog MCU pin in order to convert the output voltage.

Because the DACs output voltages are analog signals, analog multiplexers are used to connect the selected DAC output to the MCU. As there are 37 DACs, at least one 37 to 1 multiplexer is needed. As such big analog multiplexer doesn't exist on the market; several smaller multiplexer should be used. By using five 8 to 1 multiplexers, least of multiplexer input pins are wasted (5*8=40 pins, 40-37=3 pins unused). As shown in Figure 34, a sixth

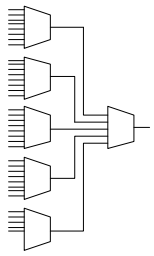


Figure 34 : Multiplexer hierarchy

[6] The CPLD chosen was available in the lab and was already used by it

multiplexer is needed to select the right output of the five multiplexers.

The *Texas Instrument SN74HC4851* [10] 8-channel analog multiplexer is chosen to fulfill the feedback channel selection task.

The CPLD is used to control the multiplexer's inputs (channel selection). An address of six bits (sel1...6) represents the DAC output to select. The first three bits select the feedback channel (FB_N1…37) and the last three bits select the right output of the five multiplexer which are selecting the feedback channel.

5.6 Detailed System Architecture

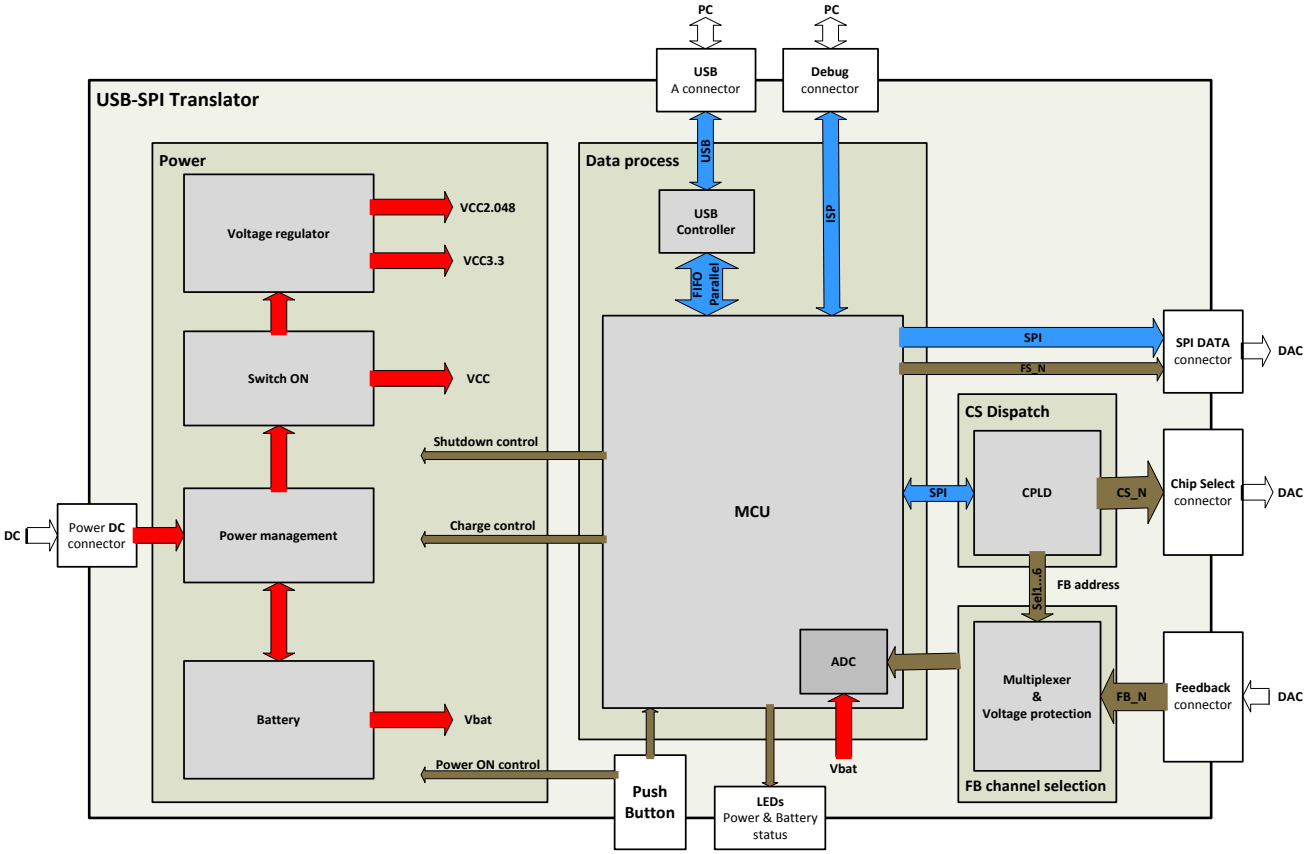


Figure 35 : Detailed System Architecture

USB-SPI Translator is divided in four sub-systems (green-brown) and several functional blocks (gray). The red links stand for electricity, blue links for data transmission, brown for signals and black links for external connections.

5.6.1 Hardware boards

The USB-SPI Translator system is divided into two electronic boards. The first one, called *USB-SPI Translator*, provide the *Power* and *Data processing* units. This board is a general USB to SPI communication interface board that could be used for any different applications involving USB to SPI

protocol communication. A detailed and complete specification document describing the *USB-SPI Translator* board is included in Appendix section A *USB-SPI Translator Board Specification*.

The second board, *CS Dispatch* which is more specific for this application, fulfills the *Chips selection* and the *Feedback channel selection* sub-systems.

Both boards, *USB-SPI Translator* and *CS Dispatch*, need to communicate together. The detailed electrical connection for data transmissions between the two boards and the connector for the DC source board is shown in Figure 36.

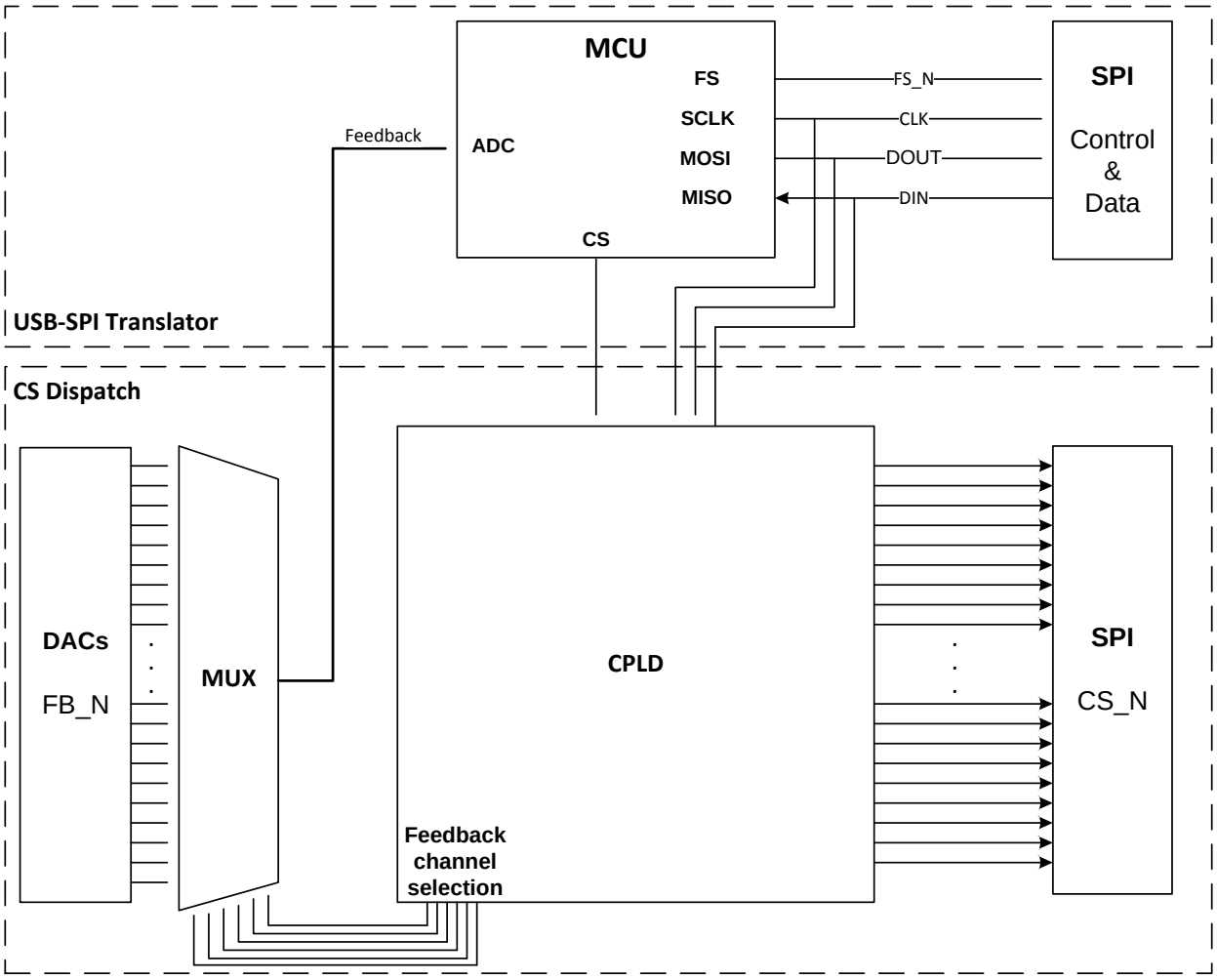


Figure 36 : Electrical connections between the two boards

5.7 PCB Design

In this sub-section the PCB designs are briefly described. The different PCB layouts are included in Appendix section C *PCB layouts.*

For convenience both PCBs size should be chosen precisely in order to be integrated to the DC source board. The different connectors are placed precisely in order to avoid complicate cables connection between the different boards.

The resulting hardware boards:

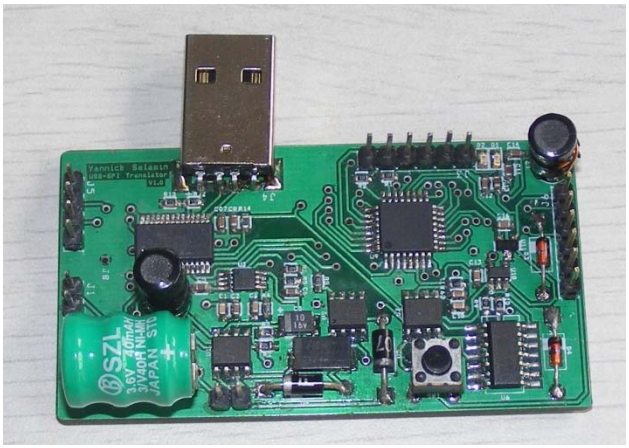


Figure 37 : USB-SPI Translator board

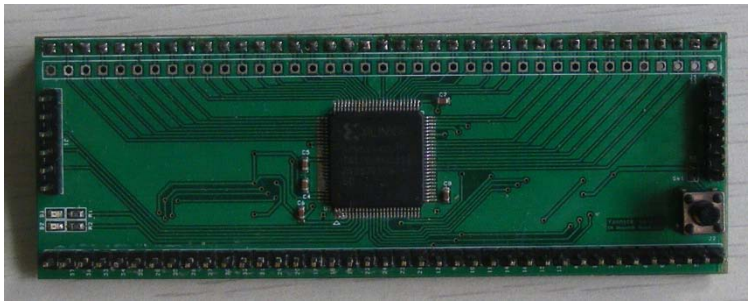


Figure 38 : CS Dispatch board (Top)

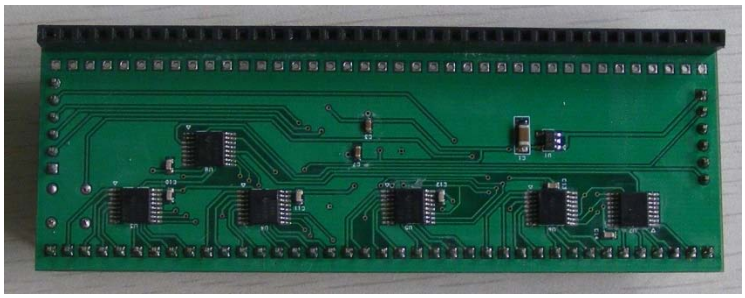


Figure 39 : CS Dispatch board (Bottom)

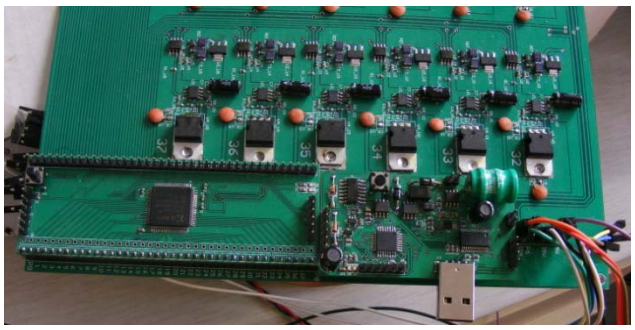


Figure 40 : USB-SPI Translator HW system

6 Software

This section describes the different firmware written for the different processing unit of the USB-SPI Translator system.

The different source codes are included in Appendix section E *Source code*.

6.1 User interface

As the requirement specifies that the user shall be able to type in the information applied on the DC source board, an application providing a graphical user interface and a bi-directional USB data communication, has to be written. This sub-section will describe the *USBFT245R* source code which is included in appendix section E *Source code*.

The programming language used for the graphical user interface and the data transfer using the FTDI driver is C++ and the software used is *Microsoft Visual Studio 2005*.

In order to realize the bidirectional communication between the computer and the FT245R USB controller implemented by the USB-SPI Translator system, a provided *FTDI* driver should be used. *FTDI* provides two types of driver, Virtual COM Port (VCP) drivers and direct (D2XX) drivers. The D2XX driver type is chosen for this application, it allows a direct access to a USB device via a DLL interface. For the bidirectional communication the application software can access the USB device through a series of DLL function calls given by *FTDI* [3].

A software example given by *FTDI* is used for the structure of the application. The application is divided in two sections, the graphical interface for the user and the bidirectional communication; both are implemented in the class *Form1*. When the application is launched the startup routine (*tWinMain*) is called. The startup routine will first create and enter in a single-threaded process. Then a new object of the class *Form1* (graphical interface) is created, which calls the constructor of the class *Form1*. The constructor class calls the *InitializeComponent()* function that initialize the graphical interface described in Section *6.1.1 GUI*.

6.1.1 GUI

The graphical interface (Figure 41) allowing the user to enter the desired information to be transmitted and displaying the received information shall provide following features:

- Display the connected device
- Types of transmission choice
- Data type in boxes
- Display the received data

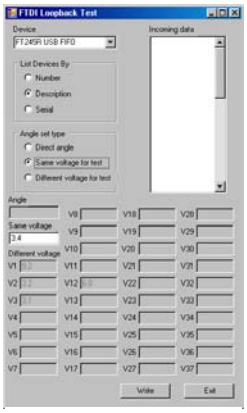


Figure 41 : GUI

As mentioned above, the initialization of the graphical interface is called by the constructor of the class *Form1*. The initialization function instances a new object for each graphic form used and load the window. Follows, the different features provided by the graphical user interface are described.

Connected device information

It's useful to know the name and the serial number of the plugged in devices. Thereby the wanted target device can clearly be chosen if several USB devices are plugged. Like the Figure 42 shows, a combo box display the selected device and radio buttons allow the user to choose the type of information to display the device.

Figure 42 : Connected device

When the application is launched the available devices are listed into the combo box. The user can manually update the device list by changing the display type. When a new device is added to the list this one is initialized by the host USB device (computer).

If a device is unplugged and plugged again, the user should update the list manually to be sure of the fully capability of the device to communicate with the computer. The same if the device is reset.

Types of transmission

Different types of transmission are needed for a well-working product. The user should be able to transmit the desired DACs output voltage of the DC source board but also transmit the final antenna angle.

As the Figure 43 shows, three different types of transmission are available for the user. For experimental tests the user can directly control the output voltage of the DACs. The user can choose between applying the same output voltage on each DAC or different output voltages for each DAC. The final purpose is to control directly the direction of the antenna by entering the angle on the computer. In order to be able to use this provided function, first the relation between the final angle, the phase shifter and the applied voltage has to be determined by experimental tests. Once the relation is known, the application will calculate the applied output voltage for each DAC matching the desired antenna angle.

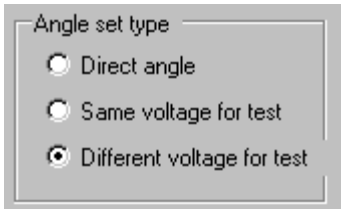


Figure 43 : Transmission types

Data type in

The user shall be able to type in the information to be sent. Text boxes are used to get the entered information by the user.

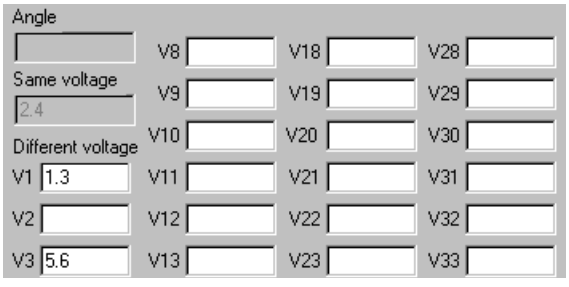


Figure 44 : GUI type in boxes (sample)

Like the Figure 44 shows, by selecting the transmission type the corresponding text boxes are enabled and the user can type in the information to be send. If the user chooses to update different voltage on each DAC, *different voltage* transmission type, a text box for each DAC is available. The user can update the desired DACs, just by type in the value in the DACs corresponding text boxes (V1…37). The entered value shall be with an accuracy of one decimal place (format X.X). If a box is empty when the information is sent, a *no change* value is sent (9.9) to inform the MCU that the DAC do not need to be updated.

Some calculations about the beam steering antenna (voltage-controlled) permitted to define the applicable values. The voltage range allowed to be applied on the phase shifter, consequently on the DACs output is between 0[V] and 5[V]. The angle change limitation of the antenna is 60[°], from -30[°] to +30[°]. By the calculations, each phase shifter voltage for each angle has been calculated. No function is available to calculate the DACs voltage for an angle. Therefore the results are included into the software as table (Angles/DACs voltage). When the user wants to update a new angle, the USB data packet is generated with the new DACs values corresponding to the angle.

Once the information to be send entered, the user can transmit the data forward the USB-SPI Translator board by pressing a provided *Send* button. The data transmission will be explained in section *6.1.2 Data transfer*.

Received data display

Due to the communication with the USB-SPI Translator board is bi-directional the user shall be able to see the received data. A list box as shown in Figure 45, displays the incoming data from the USB-SPI Translator board. Every time new information is received, the list box is cleared and the new incoming data is displayed.

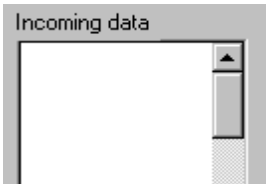


Figure 45 : GUI incoming data display

6.1.2 Data processing

The USB data transmission involves two tasks, sending and reading the data on the USB bus. By pressing the *Send* button the sending routine (*buttonSend()*) is launched and the transmission is started.

USB data generating

Before any data can be sent, the data has to match some defined format in order to be correctly read by the receiver.

The chosen transmission type is determined and the typed in values are added to a buffer (*cBuff*). Before the read data is added to the buffer, the data value is checked. When the entered value isn't in the authorized range, an information message informs the user of it. If the read box is empty a *no change* value (9.9) is added instead into the send buffer. With all the data, the software generates a USB data packet. Each USB data packet generated matches a format depicted in Figure 46.

Header		DATA
CMD	ToT	Data 1 to Data n
2 bits	6 bits	0-1022 Bytes

CMD : *10 (USB_SPI translator board)*
01 (SPI data transmission)

ToT : *00 (Single voltage update)*
0C (Same voltage update)
C0 (Direct angle update)

Data1 to Data n : *Data Bytes to process*

Figure 46 : USB data packet

Composed of a header and a data section, the USB data packets have different transmission purposes. The header indicates the type of transmission and the data section represents the new DACs values.

The voltage values (data) are transmitted in ASCII (char) type and consequently each voltage value is represented by three char bytes. The relation between numerical and ASCII (char) value is shown in Figure 47 by an example:

Type	Entered information	Byte 1	Byte 2	Byte 3
Numerical	2.6	2	.	6
Ascii (char)		0x32	0x2E	0x36

Figure 47 : Data format

Data transmission

For the data transmission two main routines are used, the *btnSend_Click*() function for the sending routine and the *ReadingProc*() function for the reading routine.

The send routine launched by the *Send* button is in charge for several tasks listed below:

- Get the user data information
- Generate a USB data packet with the data
- Create and start the reader thread
- Set the transmission parameters
- Write the data on the USB bus
- Display the incoming data

The read routine is launched by a separated specific reader thread. The reader thread is created and started by the send routine. Once the read routine started, the function wait (thread sleeping) for a notification event. A notification event is set when a character has been received and will unblock the read routine.

A sequence diagram showing a data transmission is shown in Figure 48.

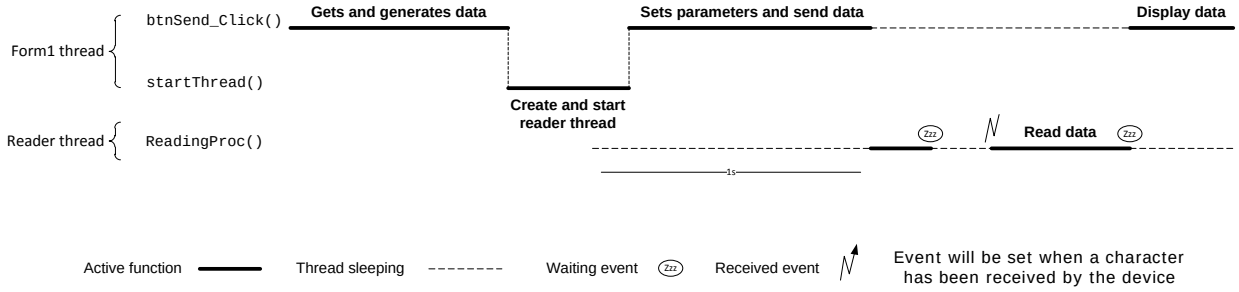


Figure 48 : Sequence diagram of transmission

The Figure 48 shows that the tows first above listed tasks are executed by the send routine when the reader thread doesn't exist yet. When the USB data packet has been generated the send routine checks that a USB device is selected and ready to communicate. If no device is found, an advertisement message will inform the user.

In case one device is ready, the *startThread*() function is called by the send routine. The sub-routine creates the reader thread that execute the *readerProc*() function. After the thread was created and started it is put asleep for 1000ms allowing the send routine to continue.

In order to have a correct USB communication, a couple of settings have to be set first. The event notification condition is set up in order to set an event when a character has been received by the device. The speed transmission (baud rate) has to be set and the chosen baud rate for the bidirectional communication is **9600[bps].**

When the transmission parameters are set, the provided DLL function *FT_Write()* is used to write on the USB bus. The *FT_Write()* function takes four parameters as follow:

- ftHandle : Status of the device.
- IpBuffer : Pointer to the buffer that contains the data to be written to the device.
- dwBytesToWrite : Number of bytes to write to the device.
- IpdwBytesWritten : Pointer pointing to the number of bytes written to the device.

If all parameters correct, the DLL function send the data to the USB controller device.

One second after the reader thread was created, the thread wakes up and launches the *readerProc()* function. The reader routine check if an event has occurred (data received). If not, the function blocks on the event and the send routine becomes active.

When some data is received a notification event is set and the reader thread is unblocked. The number of received bytes is found out by the FT_GetQueueStatus() function. The provided DLL function takes two parameters as follow:

- ftHandle : Status of the device.
- IpdwAmountInRxQueue : Pointer to the number of bytes in the receive queue.

A loop reads one by one every received byte. The read byte is converted to a string character and stored into a receive buffer (*buff*). The provided DLL function *FT_Read()* is used to read the incoming bytes. Four parameters are taken by the reading function:

- ftHandle : Status of the device.
- IpBuffer : Pointer to the buffer that receives the data from the device.
- dwBytesToRead : Number of bytes to be read from the device.
- IpdwBytesReturned : Pointer pointing to the number of bytes read from the device.

When all the received bytes are read and stored into the *buff* buffer, the reader routine will block on the event until some next data is received.

Data displaying

Due to the reader routine is a separated thread, the graphic objects aren't available from the readingProc() function and the display of the data should be done by a sub-routine. The sub-routine reads the *buff* buffer and displays the data in the list box.

6.2 USB-SPI Translator

The processing unit for the USB-SPI Translator board is the *ATmega88* microcontroller. This sub-section describes the embedded firmware written for the MCU. A detailed analyze of the needed software permitted to describe the firmware by flowcharts which have helped to write the source code. The resulting flowcharts of the analysis are included in appendix section D *MCU Firmware Flowcharts.*

As central control unit, the MCU has to communicate with the computer, the CS Dispatch board and the DC source board. The MCU communicates with the computer through the USB controller (FT245R) by FIFO parallel operation. For the CS Dispatch board and the DC source board the communication interface used is SPI protocol.

The MCU integrated in the USB-SPI Translator board is in charge for the following tasks:

- Startup
- Read USB data
- Received data analysis
- DAC update
- DAC feedback processing
- Write USB data
- Battery charging management

When the MCU gets supplied, the ***main()*** function of the program is launched. It calls the startup routine which is the ***init()*** method. All the register and I/O of the MCU are set at their initial values. After that the program enters in an infinite loop of data processing. The endless loop processes all of the listed tasks above but Startup. The loop checks if a flag for a task is set, if yes the software will execute the corresponding task. The flags are set by interrupt sub-routine (ISR) or by the tasks themself in order to execute another task. Follows, the different MCU tasks are discussed and depicted.

6.2.1 Startup

Like mentioned above the startup task is the initialization of the USB-SPI Translator board. The *init()* function is the first routine called by the switch on of the MCU. The status register (SREG), I/Os and all used MCU peripherals are initialized by setting the registers to their initial values.

I/O

All connected pins are either input or output signals. In order to control or read correctly a pin both, direction and the initial status, have to be set.

TIMERS

The ATmega88 microcontroller provides two 8-bits Timers (*TIMER0* and *TIMER2*) and one 16-bit Timer (*TIMER1*). *TIMER0* and *TIMER1* are used to execute respectively 1ms and 1s interrupt-sub routine.

The two timers are initialized as follows:

Parameters	TIMER0	TIMER1
n-bits timer [bits]	8	16
Output timing [ms]	1	1000
Clock prescaler	8	64
Output compare value (A register)	250	15625
Interrupt enable on output match	YES	YES

Interrupt

The ATmega88 device provides several different interrupt sources with each a separate program vector in the program memory space. When an interrupt occurs, the corresponding interrupt sub-routine (ISR) is triggered if the interrupt source is enabled. In addition to the two internal timers interrupt sources, the system use two external interrupt sources. External interrupt occurs if one of the enabled pin toggles. Below the two external sources:

Parameters	RXF#	Button
Pin	PB6	PC2
Usage	USB Read	Shutdown

SPI

As mentioned above, the provided SPI interface is used as communication interface. The SPI interface of the MCU is initialized as follow:

Parameters	SPI
Operation type	Master
Transmission speed	clk/2
2x speed enable	YES
SPI data mode	3
Data order	MSB first
End of transmission interrupt	YES

ADC

In order to have accurate analog-to-digital conversions, the built in ADC has to be initialized as follow:

Parameters	ADC
Analog source	ADC6 (feedback)
Voltage reference source	Extern (2.5[v])
Clock prescaler	8
End of transmission interrupt	YES

When the initialization is finished the data processing can start. Every time the microcontroller is reset, the initialization is executed firstly.

6.2.2 Read USB data

When the USB controller has data to transmit to the MCU the USB device pulls down the RXF# pin. As mentioned above the RXF# pin is an interrupt source and launch the corresponding ISR (*PCINT0_vect*) when the pin toggles. The *PCINT0_vect* ISR reads byte per byte the data from USB controller and stores the data into the read buffer (*tUSBRD*). The read function was written according to the time diagram [3] in Figure 49, representing a read cycle for one byte.

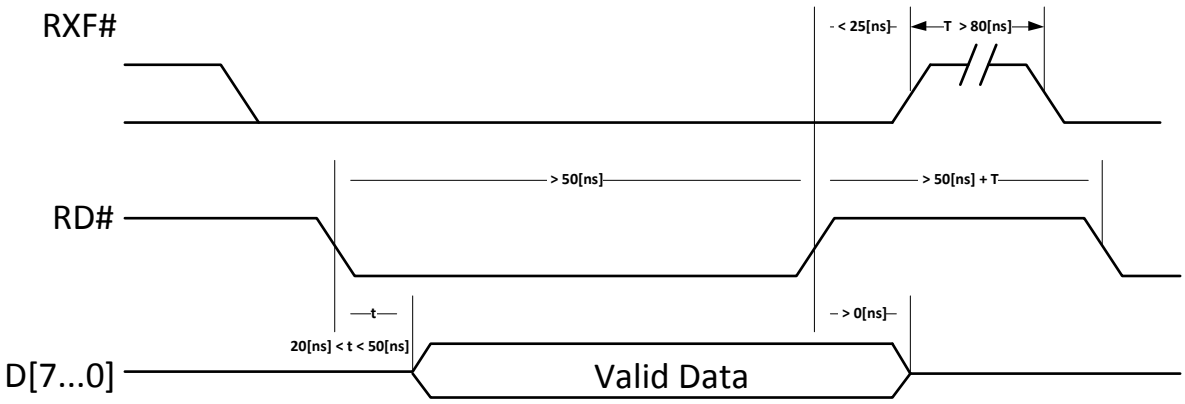


Figure 49 : USB data read timing diagram

By each reading the MCU reads 1byte of data on the port D and store it into the read buffer of type *char* (8 bits). As the voltage value send by the user are composed of two digits and a comma, one voltage value takes three bytes in the buffer. Before the received values are able to be used, the software has to transform the received value over three *char* into one value of type *float* that can be used further. The new translate value is stored into a new data buffer (*tDACWR*). The follow relations are used to reconstruct the received value into a *float* variable:

```
data = (float)tUSBRD[1] - 48;
data += ((float)(tUSBRD[3] - 48))/10;
```

To transform a char number into a numerical (int, float) value, the char value is subtract by 48 (ASCII). For the second relation, the value is divided by ten due to it's the decimal digit. The transformation relation is shown in Figure 47 page 34 by an example.

When the data has been read, translate and stored into the *tDACWR* buffer, the *fUSBRD* flag is set.

6.2.3 Received data analysis

When the MCU has received data from the USB controller, the *fUSBRD* flag is set and thereby the analysis of the received USB data is executed.

The first byte of the received buffer (*tUSBRD*), which stands for the USB data header, is analyzed. As described in section *6.1.2 Data processing*, the USB data header is composed of two parts, *CMD* (2 bits) and *ToT* (6 bits). The two CMD bits define if the transmitted data is configuration information for the USB-SPI Translator board or new information for the DC source board. The ToT bits represent the type of transmission the user chose.

If the USB data packet received is for a DC source board update, the type of transmission is determined (ToT). Knowing the type of transmission, the corresponding sub-routine is called in order to update the DACs with the received data. Each transmission type is processed differently and thereby a sub-routine for each type is implemented. However to write a new value on a DAC the sub-routine (*SPI_DAC_WR*) stays the same (see section *6.2.4* DAC writing). As explained further, to update a DAC, two parameters are used.

- Index : Number of DAC to update
- Data : Digital voltage value to update

Those two parameters are determined by the different transmissions sub-routines described below. As the entered information by the user is a numerical voltage value, the software has to determine the corresponding digital value to write to the DAC device. The *New_DAC_Value()* function returns the digital information that has to be written to the DAC. The relation to determine the digital input value for the digital-to-analog converters is as follow:

$$DAC = \frac{\frac{data*2^n}{2*Vref}}{Ampli} + V_{DAC\ offset} \ ; \ n = 10, Vref = 2.5[V], V_{DAC\ offset} = 3.6[V], Ampli = 5 \qquad (7)$$

Same Voltage Process

To update all the DACs with the same voltage, all the chips selection are pulled down. Thereby all the DACs read the SPI data line and are updated at the same time and only one data transmission is necessary. To select all the DACs, the chips selection value to send to the CPLD is *index* = **50** (refer to section *6.2.4 DAC update*).

Single Voltage Process

When the user chose the *different voltage* transmission, he can chose to update every DAC, just a few DACs or only one. The sub-routine checks for each DAC if it has to be updated by the corresponding values. As explained in section 6.1.1 GUI, when the user chose a different voltage transmission, the empty left input boxes are set with a *no change* value. The sub-routine run through the new data buffer (*tDACWR)* and checks each value. When the initial value is matched, nothing is done and the next value is checked by incrementing the buffer index. If the value checked isn't a *no change* value, the DAC update function (*SPI_DAC_WR*) is called. The parameters to update the DAC are:

- Index : Buffer index.
- Data : Data matching the buffer index.

Each time a DAC is to update, the *SPI_DAC_WR* routine is called with the correct parameters.

Direct Angle Process

When the user enters a direct angle in order to update the antenna direction, the DACs output voltages are calculated by the user interface application and send to the MCU. The direct angle process is similar to the different voltage process by the exception that every DAC is updated with a new value. Thereby no value check for a *no change* value has to be performed.

- Index : Buffer index.
- Data : Data matching the buffer index.

The *SPI_DAC_WR* routine is called with the correct parameters for each DAC.

6.2.4 DAC update

In order to write a new value to a digital-to-analog converter device, the *SPI_DAC_WR()* function is called. The function takes two parameters as follow:

- Index : Number of DAC to update
- Data : Digital voltage value to update

As mentioned in section *6.2.3 Received data analysis*, the *SPI_DAC_WR()* function is called by the transmission type sub-routine in order to update the DACs. Figure 50 represent a DAC update cycle.

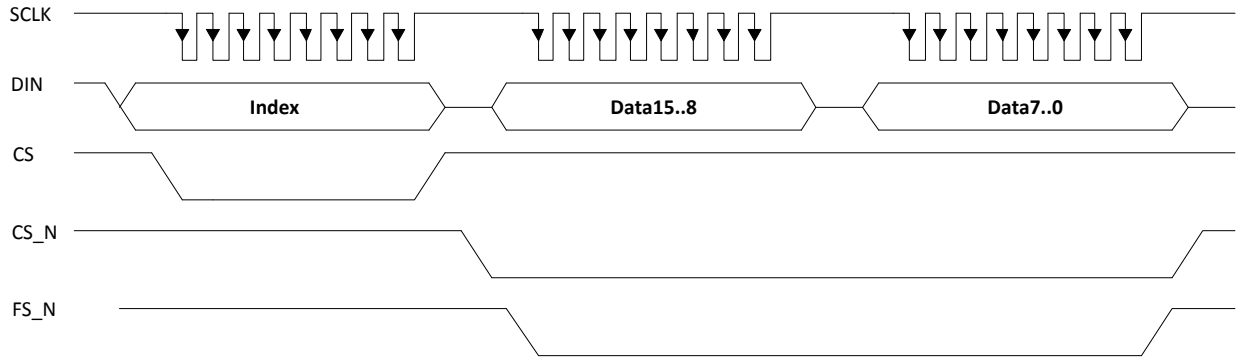


Figure 50 : DAC update time diagram

To write a new value to the DAC, first the chip selection number (Index) has to be transmitted to the CPLD. As shows Figure 50, the first SPI transmission is the index value to the CPLD. This way, the CPLD can select the DAC that has to read the new value. When the DAC is selected the data can be sent to the DAC. Due to the DACs are 10-bits converters, two SPI transmissions (8-bits) are necessary to update a new value. The data format of the 16-bits transmission is represented below:

D15	D14	D13	D12	D11	D10	D9	D8	D7	D6	D5	D4	D3	D2	D1	D0
X	SPD	PWR	X	New DAC value (10 bits)										0	0

- SPD : Speed control bit (0 – Normal mode)
- PWR : Power control bit (0 – Normal operation)

When the device has been enabled with its chip selection (*CS_N*) set low, a falling edge of *FS_N* starts shifting the data bit by bit on the falling edges of *SCLK*, starting with the MSB, into the internal register of the DAC device.

In order to inform the CPLD that the DACs update is finished, a **0x00** index transmission is performed. Thereby the CPLD disables all the DAC from reading by pulling up all the *CS_N* signals (see section *6.3.1 Firmware*).

6.2.5 DAC feedback processing

The built in analog-to-digital converter is used to convert the output voltage of the DACs. A DAC feedback update happened when the *fFB* flag is set. The *TIMER1* ISR set the *fFB* flag by the set frequency. The frequency can be controlled by one second precision as the *TIMER1* ISR is executed every second.

When the *fFB* flag is set, the *FB_Process()* is started and a new DAC data feedback update is executed.

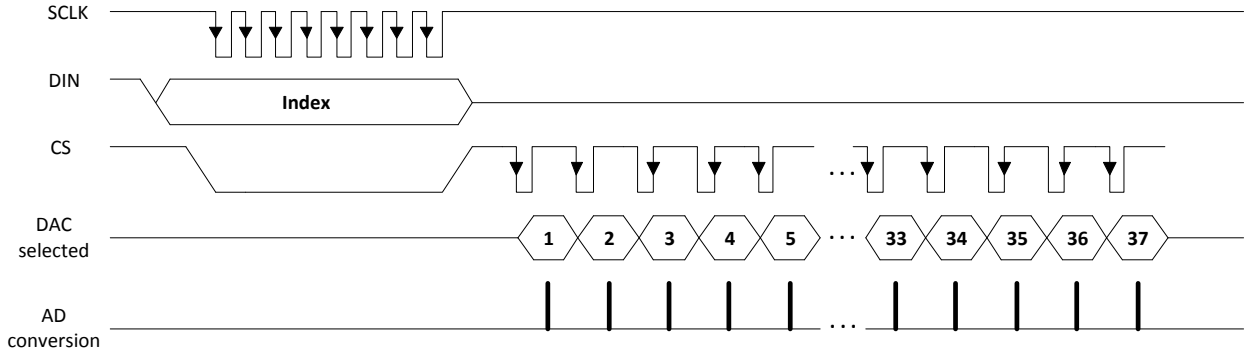


Figure 51 : DAC data feedback time diagram

Figure 51 shows a DAC data feedback cycle. First the CPLD is informed of a feedback update by transmitting the index = **0x64**. The CPLD selects the feedback data source (DAC) to convert (see section 6.3 CS Dispatch). By strobbing the CS signal, the CPLD increment the feedback data source (DAC). For each feedback data source (DAC) an analog-to-digital conversion is done and the obtained digital value of the DAC output voltage is stored into a buffer (*tFBData*). Like the DACs, the built in ADC is a 10-bits converter; thereby the conversion results are using two 8-bits buffer inputs.

When all the DACs have been converted, a USB data packet has to be generated with the stored data into the *tFBData* buffer. Each digital result (ADC) has to be translated into a numerical value (format X.X) according to the following relation in order to send the information back to the computer:

$$V_{DAC} = \frac{ADC * V_{ref} * AMPLI}{1024} - V_{offset} \qquad ; \; V_{ref} = 2.5[V], AMPLI = 5, V_{offset} = 3.5[V] \qquad (8)$$

To generate the USB data packed, each DAC output value has to fit with the data format described in section *6.1.2 Data processing* (see Figure 47). To generate the data packet, which are stored into the USB write buffer (*tUSBWR*), the numerical value has to be translated into char values (3 bytes) like described above in the *Read USB data* sub-section. Below are shown the used relation:

```
tUSBWR[i] = ((int)(data)) + 48;
tUSBWR[i+1] = '.';
data = (int)((data*10)-(((int)(data))*10));
tUSBWR[i+2] = ((char)data) + 48;
```

To have a complete and ready USB data packet to be sent, the USB data header has to be set in the first position of the USB write buffer (*tUSBWR*).

6.2.6 Write USB data

To write the generated USB data packet contained into the *tUSBWR* buffer, the *USB_WR_Data_Process()* function is used. The USB data write routine has been written according to the USB data write cycle represented in Figure 52.

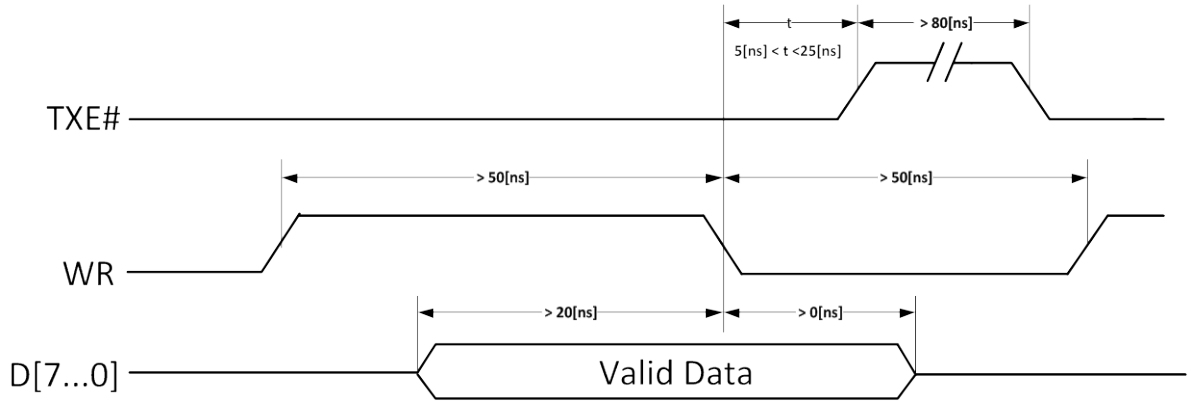


Figure 52 : USB data write time diagram

Data can only be written into the USB controller when the *TXE#* signal is low. When the *WR* signal goes from high to low, the data byte set on the port D is written into the USB device. When a writing cycle is over the next byte is set on the port D for the next write cycle. When the MCU has finish to write the data into the USB controller, the port D has to be set back as input in order to be able to read future incoming USB data packet.

6.2.7 Battery charging management

As the MCU is used to control the recharge of the battery, the built in AD converter is used to have a feedback information of the battery charge. Every five second the *fBAT* flag is set by the *TIMER1* ISR and the battery management routine is executed (*Battery_Process*).

The battery source is connected to the MCU through the analog ADC7 pin. Before the conversion can starts the battery source channel (ADC7) has to be selected. To have a more accurate conversion the battery shouldn't be recharging during the conversion, thereby the *charge* signal is set high. Then a conversion of the battery voltage level is performed by the AD converter. In order to check the battery level, the conversion result has to be translated into a numerical format as follow:

$$V_{FBbat} = \frac{ADC * V_{ref}}{1024} \qquad ; V_{ref} = 2.5[V] \tag{9}$$

As explained in section 5.2.2 MCU (ADC), the battery is connected to the analog input through a voltage divider. Before the numerical battery level can be checked the real battery level has to be calculated as follow:

$$V_{bat} = V_{FBbat} \frac{RBAT2}{RBAT1} \qquad ; RBAT1 = 300, RBAT2 = 200 \tag{10}$$

If the battery level is beneath the low threshold, the *charge* signal is set low in order to recharge the battery. While the battery is recharging or if no external source is available, in this case has to be recharged, the battery LED is lighting. When the battery level exceeds the high threshold, the *charge* signal is set high and the battery stops recharging and the battery LED is switch off. If the battery level is between the thresholds a variable with the last recharging status is checked and if the battery was recharging, the *charge* signal is set back low. If the battery wasn't recharging the *charge* signal is kept high.

6.3 CS Dispatch

The CS Dispatch board uses a complex programmable logic device (CPLD) as processing unit. The development software *HDL Designer* from *Mentor Graphics* is used. HDL Designer is a project manager based on VHDL or Verilog languages that can automatically generate VHDL text from graphs (Block diagrams, state diagrams). The firmware is written in VHDL.

The three tasks the CPLD has to fulfill are:

- Read MCU data
- Chips selection
- Feedback channel selection

When the MCU transmit some information to the CPLD, the device analyzes the received data and then executes the request.

6.3.1 Firmware

As HDL Designer allows graphics design, the top level of the firmware is described with block diagrams (module). Figure 53 shows the TOP level architecture.

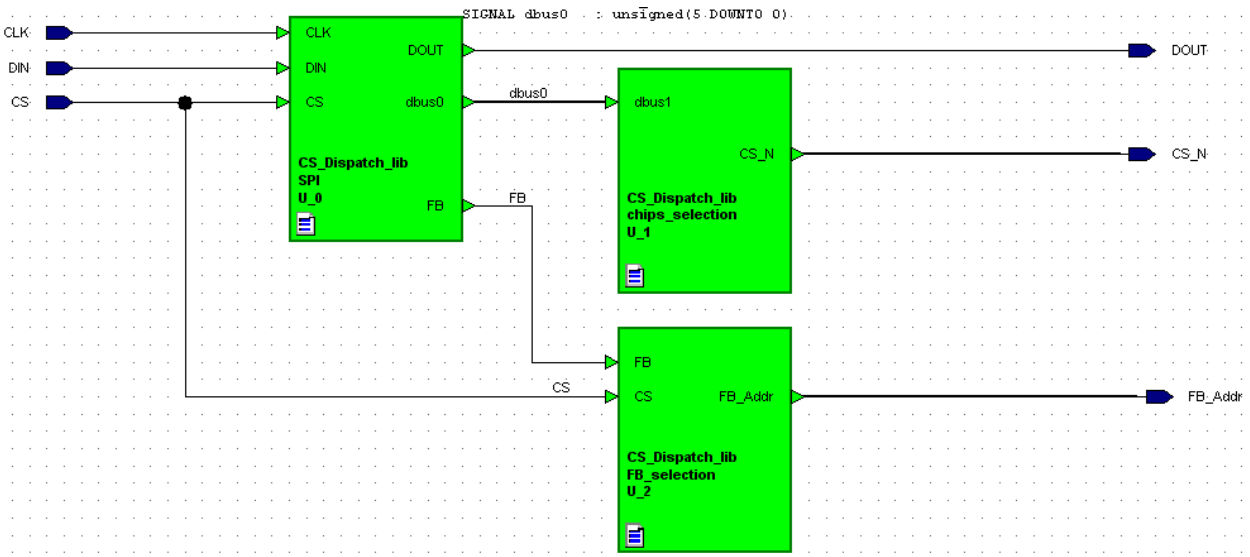


Figure 53 : CS Dispatch TOP level

Name	Type	Size	Direction	Description
CLK	Signal	1	Input	Clock signal
DIN	Signal	1	Input	SPI data input (MOSI)
CS	Signal	1	Input	Chip selection (CPLD) for SPI transmission
DOUT	Signal	1	Output	SPI data output (MISO)
CS_N	Bus	37	Output	DAC selection
FB_Addr	Bus	6	Output	Feedback channel selection
dbus0	Bus	6	Intern	Numerical chip to select
FB	Signal	1	Intern	Start a feedback update signal

The buses and signals used by the CS Dispatch TOP level are described above. The implemented modules are described in the following sub-sections.

MCU communication (SPI)

By pulling down the *CS* signal the MCU start a SPI transmission with the CPLD. The SPI module is in charge to read the incoming 8-bits data from MCU.

On each falling edge of *CLK* (clock) the *DIN* pin is read and the value stored into an internal 8-bits bus. With *CS* going high the transmission is over and the SPI module determines the request to execute. If the received data is **0x64** (100), an impulsion on the *FB* signal executes the feedback channel selection module. If not, the received data stand for the DAC to select and therefor the data is transmitted to the chips selection module through the internal *dbus0* bus.

Chips selection

By sending a numerical number between 0 and 50, the MCU wants the CPLD to select the DAC by pulling down the corresponding *CS_N* [1…37] signal matching the transmitted value. A switch/case structure is used to select the DAC signal. The received value/DAC relations are represented in the table beneath.

MCU data	Numerical value	DAC to select
0x00	0	None
0x01	1	CS_N1
0x02	2	CS_N2
0x03	3	CS_N3
…	…	…
0x23	35	CS_N35
0x24	36	CS_N36
0x25	37	CS_N37
0x32	50	All CS_N[1…37]
0xFF	255	FB channel selection

FB channel selection

If the value 0xFF is received the SPI module generates an impulsion on the *FB* signal that starts a DAC output feedback update. The FB channel selection module is in charge to select the DAC that the output voltage has to be connected to the analog input of the MCU in order to be converter. To fulfill the selection the *FB_Addr* bus represents the address of the DAC to be select. The first DAC to be update is the device number one. By pulling down and high the *CS* signal the MCU increment the selected DAC (see Figure 51).

6.3.2 Simulation

Mentor Graphics provides software able to simulate hardware description language like VHDL. The simulation software called *ModelSim XE* is used to simulate the written VHDL code.

A test bench is implemented in order to generate the input signals and to get the output signal and buses. The table below shows the input signals generated by the test bench for the simulation.

Input	Generated signal	Frequency/Data	Description
CLK	Clock	500Hz	SPI clock signal from MCU
DIN	Pulses	0x09, 0x1C, 0x14, 0x00 0x64	Chips selection (DAC update) Feedback channel selection
CS	Pulses	≤ 8 clock pulses 37 pulses	SPI chip selection (CPLD) Incremental signal for FB update

Two simulations are done, one testing the *Chips selection* function and one testing the *Feedback channel selection*.

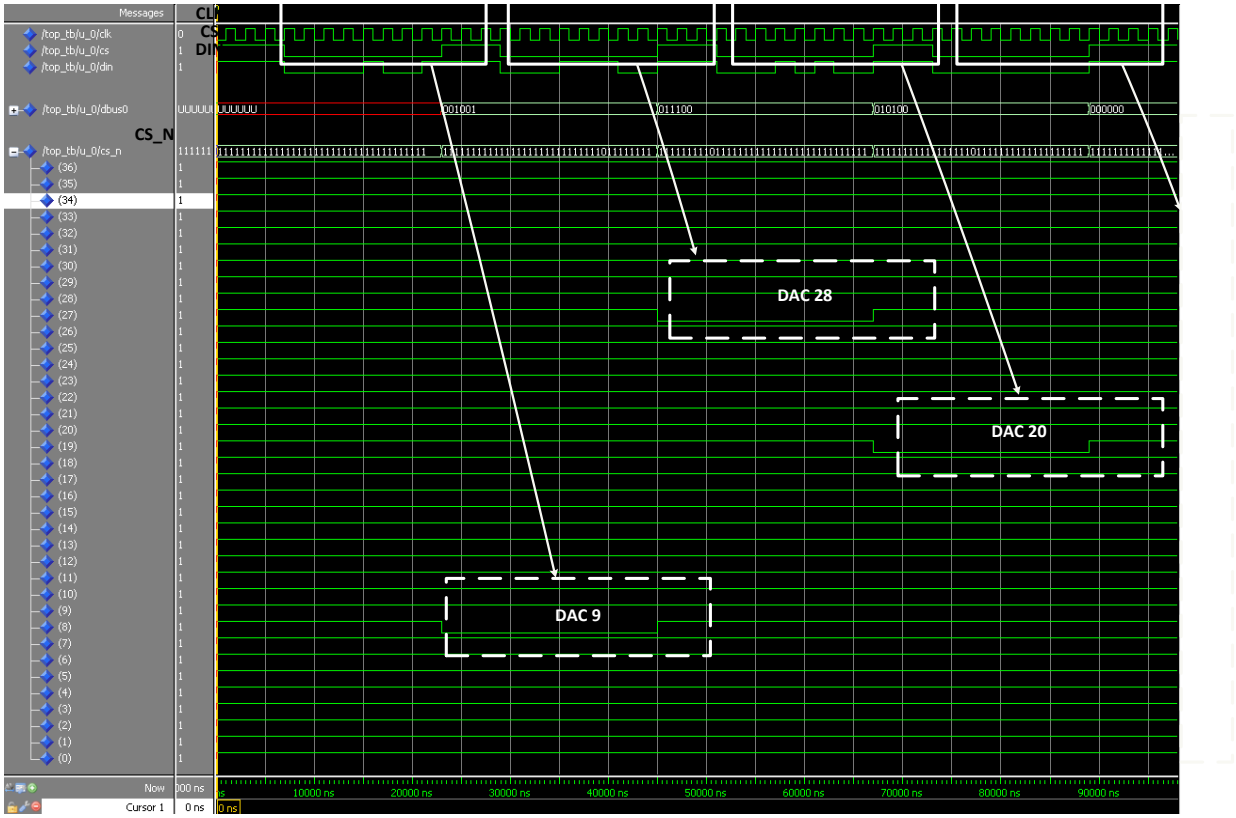


Figure 54 : Chips selection simulation

Figure 54 shows the simulation result for the Chips selection module. The simulation shows clearly that after received the data (white rectangle) the corresponding DAC is selected (white dashed rectangle).

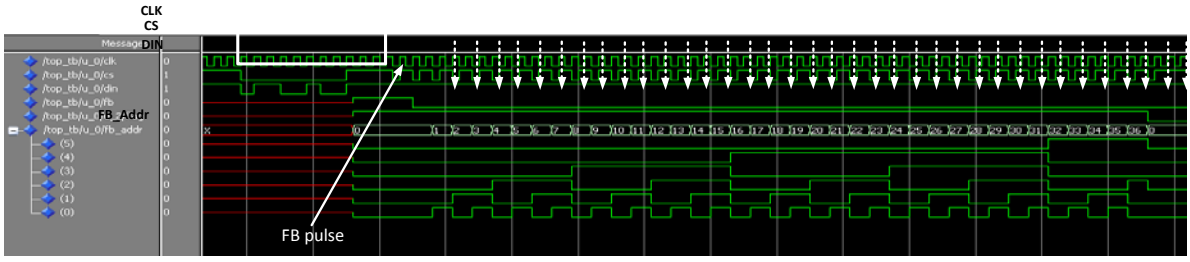


Figure 55 : FB channel selection simulation

The simulation in Figure 55 shows that by receiving the value **0x64** from MCU, the CPLD generate a pulse on the *FB* signal and thereby start a FB channel selection. For each falling edge of *CS*, when *flag* is high (DAC FB update), the feedback channel is incremented.

6.3.3 Synthesis

This sub-section describes how *Xilinx ISE Design* is used for the synthesis and the upload of the CS Dispatch firmware into the CPLD.

When the VHDL code is uploaded into the CPLD device, the pins have to match with the input and output signals. If nothing is done, Xilinx allocate the inputs and outputs randomly to the pins. *Precision Synthesis* is a software allowing to set synthesis constraint, like pin allocation or timing constraints. The following pin allocation is set for the synthesis according to the schematic (see Appendix section A *Schematic*):

Input / Output	Pin
CLK	22
DIN	6
CS	8
DOUT	7
CS_N [0:36]	35,36,37,39,40,41,42,43,49,50,52,53,54,55,56,58,59,60, 61,63,64,65,66,67,68,70,71,72,73,74,76,77,78,79,80,81,82
FB_Addr [0:5]	11,12,13,14,15,16

The **.ucf* file generated, containing all the synthesis rules, is included to the Xilinx ISE project in order to run the synthesis with the correct pin allocation.

7 Experimental results

In this section the realized experimental tests are described. First the USB-SPI Translator system is tested. Finally experimental tests about the whole system, including the DC voltage control beam steering metamaterial antenna, are done to prove the well-working of the product.

For the USB-SPI Translator board, hardware and software have been tested.

7.1 Power management

7.1.1 Power selector

In order to test the power selector circuitry, the battery outgoing current flow is measured.

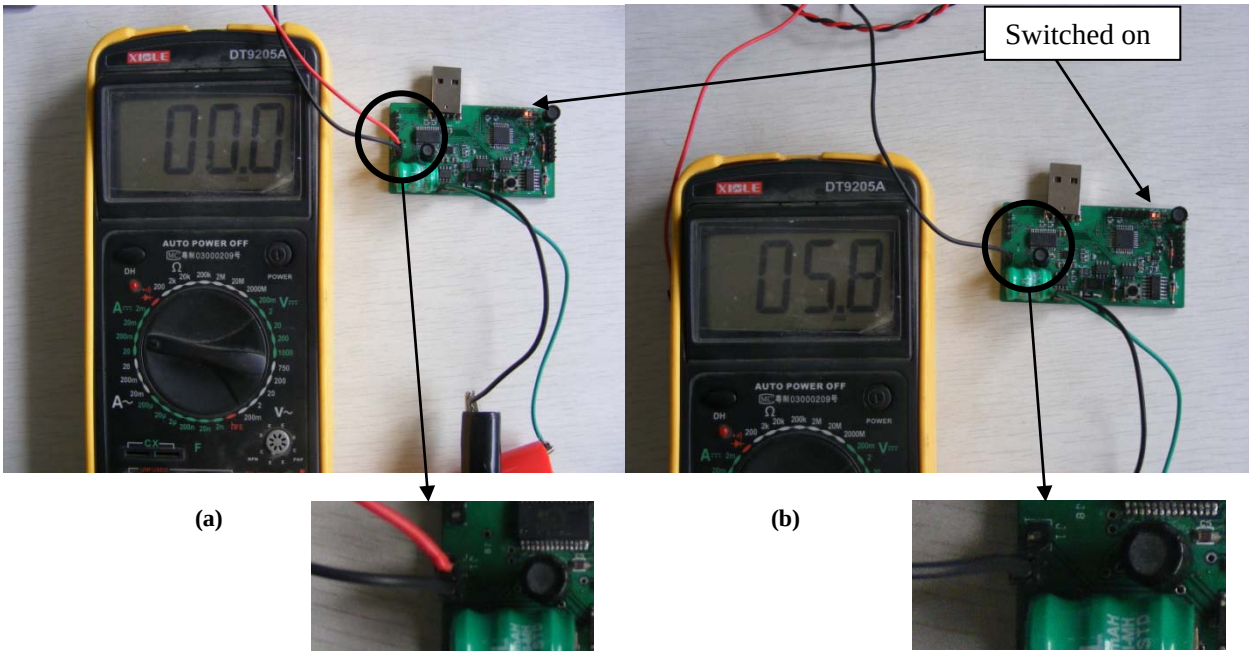


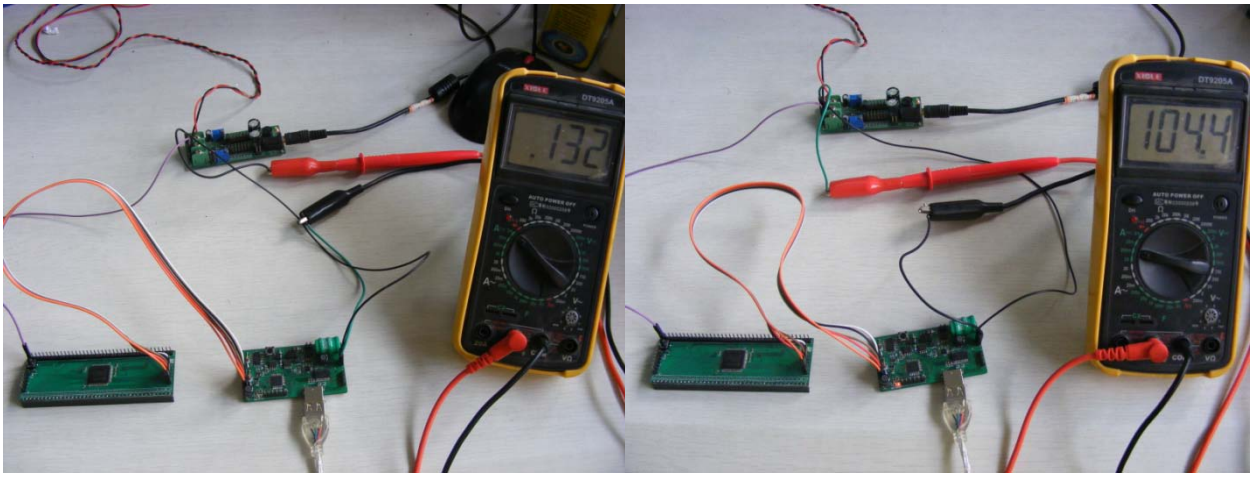
Figure 56: Battery output current (a) with external power source, (b) without external power source

As Figure 56 (a) shows, the current drawn from the battery is null when external power supply is available. However if no external supply is available, Figure 56 (b) shows that current is drawn from the battery in order to supply the system. The test demonstrates that the power selection works and that the battery is able to supply at least the data processing unit (MCU).

7.1.2 Power consumption

To have a precise idea of the power consumption, two kinds of measurements are done, with external supply and by battery supply. For the tests the whole USB-SPI Translator system is connected.

External supply

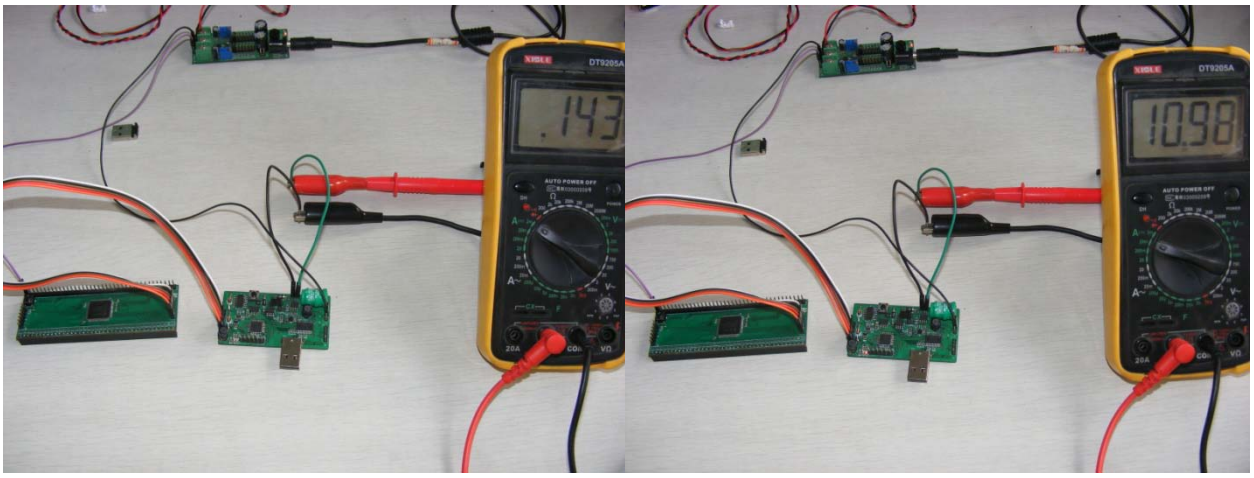


(a) (b)

Figure 57 : Power consumption by external supply (a) switched off, (b) switch on

$I_{switch\ off}$ = **132[µA]** $I_{switch\ on}$ = **104.4[mA]**

Battery supply



(a) (b)

Figure 58 : Power consumption by battery supply (a) switch off, (b) switch on

$I_{switch\ off}$ = **143[µA]** $I_{switch\ on}$ = **10.98[mA]**

Figure 57 and Figure 58 (a) show that even when the system is shut down a small current is drawn. The user should be able to switch on the system by a push button. In order to fulfill the requirement a small electronic is needed to switch on the system and consequently a small current is drawn.

Figure 58 (b) shows that the battery capacity is too small to supply the whole system, but enough to supply the data processing unit (MCU) and keep safe the data.

7.1.3 Inputs protection

In order to test the input protection system, an external voltage generator is used to apply the different voltage on the input connector. The voltage range tested is from 0[V] to 25[V]. The results of the experiment are presented in the table below:

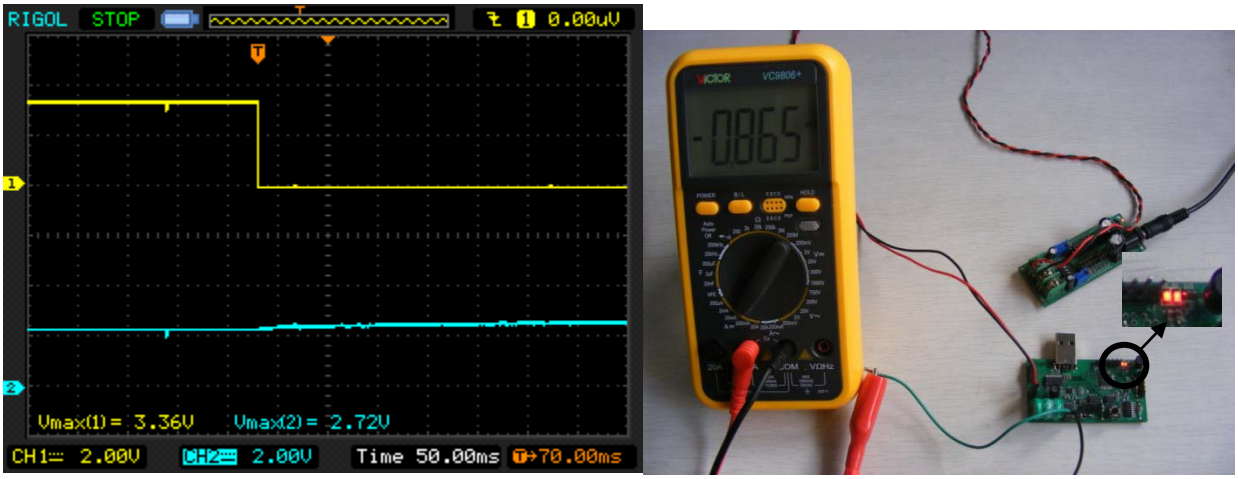
Applied voltage [V]	MCU Voltage [V]	Description
0	0	Data
0.51	0.51	
1.10	1.10	
1.65	1.65	
2.05	2.05	
2.37	2.37	
2.50	2.49	
2.90	2.88	No use
3.30	3.12	
3.60	3.29	
5.03	3.83	Over voltage
10.02	4.20	
15.01	4.42	
25.07	4.51	

The experiment shows that under 3[V] the diode doesn't drive and the applied voltage is directly applied on the MCU. Above 3[V] the diode starts to drive and consequently a voltage drop appears on the resistance. For voltages over 5[V] the diode drives fully and the voltage is low down by the resistance.

The experiment shows that the inputs protection work and that the MCU is protected.

7.1.4 Battery management

By measuring the battery voltage level and the *charge* signal from MCU, the battery management system can be tested. For the tests, the low threshold is set at 3[V] and the high threshold at 3.6[V].



(a) (b)

Figure 59 : Battery management (a) start of recharging signal, (b) battery charging current

$$I_{charge} = \mathbf{-865[\mu A]}$$

Figure 59 shows the *charge* signal (yellow) and the battery voltage level (bleu). When the battery level is converted by the MCU and the voltage level is under the low threshold, the *charge* signal is set low and the battery is being recharged. Figure 59 (b) shows the battery current. If the current is positive, the battery is supplying the system. In the opposite, if the current is negative, the battery is recharged. When the battery is recharged the second LED is lighting (see zoom in Figure 59 (b)).

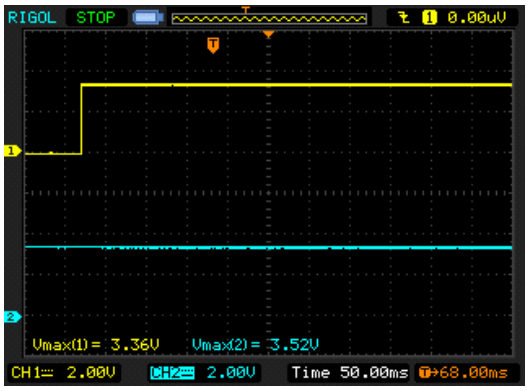


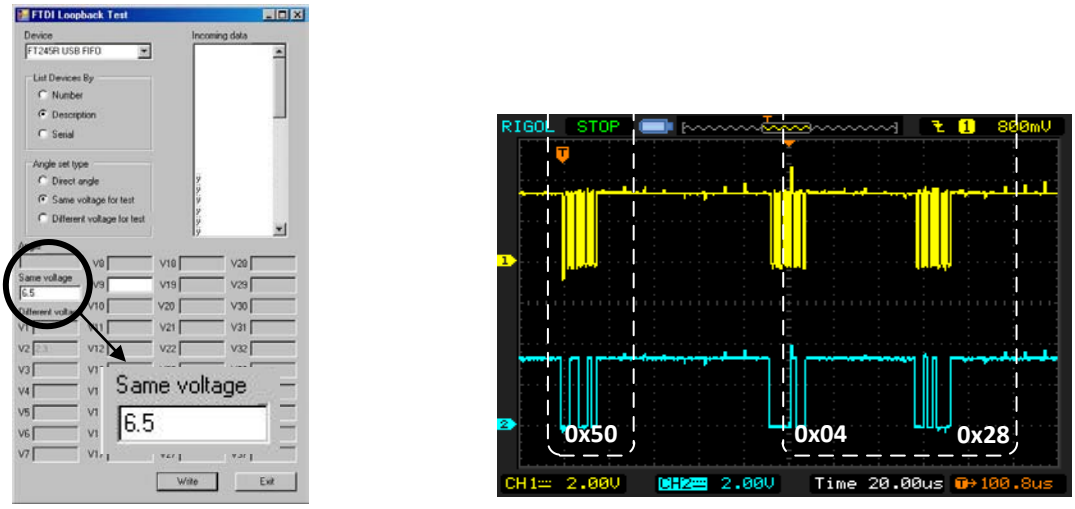
Figure 60 : Battery stops recharged

Figure 60 shows the battery reaching the high threshold and consequently the *charge* signal (yellow) is set high and the battery stop recharging.

7.2 Data transmissions

For the data transmission, the three types of transmission are tested. For the following data transmission pictures, yellow signals represent the SPI clock and the bleu signals the SPI data signal. As the DACs have a offset of 3.5[V], the output voltage differs with the entered user information. Therefor the offset isn't applied for the data transmissions tests, in order to verify that the data send correspond to the typed in value. For the global system experiment (see section 7.3 USB-SPI Translator system) the offset is set back.

7.2.1 Same voltage



(a) (b)

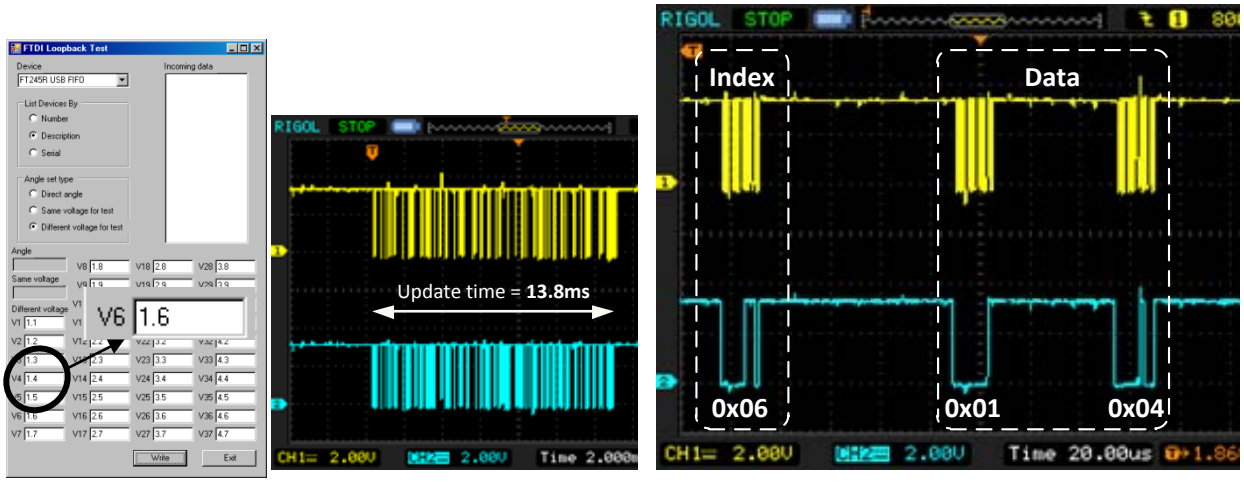
Figure 61 : Same voltage transmission (a) GUI, (b) 6.5[V] data transmission

Index: 0x50 => **All DACs** ; Data: 0x0428 => new value: 0x10A => $V_{DAC} = \frac{0x10A * 2 * V_{Ref} * 5}{1024} = 6.5[V]$

For the same voltage transmission, only one transmission is needed. As Figure 61 shows, the index number sent to the CPLD in order to select all the DACs is **0x50.** The new value transmit to the DACs is **0x10A** which correspond to **6.5[V]**.

7.2.2 Different voltage

Complete DACs update

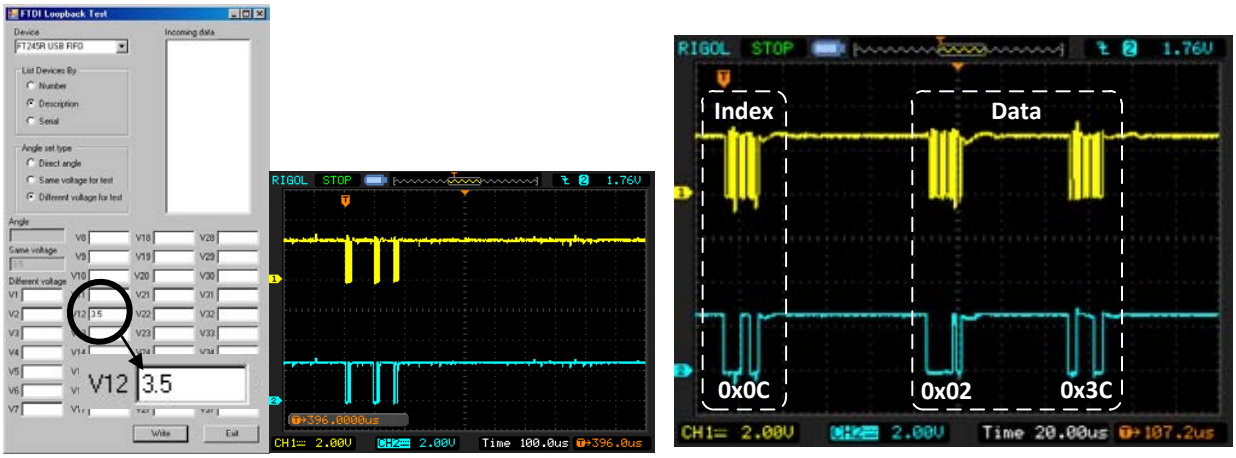


(a) (b) (c)

Figure 62 : Different voltage transmission for each DAC (a) GUI, (b) all data transmission, (c) DAC 6 data transmission

Index: 0x06 => **DAC 6** ; Data: 0x0104 => new value: 0x41 => $V_{DAC} = \frac{0x41 \times 2 \times V_{ref} \times 5}{1024} = \mathbf{1.6}[V]$

Single DAC update

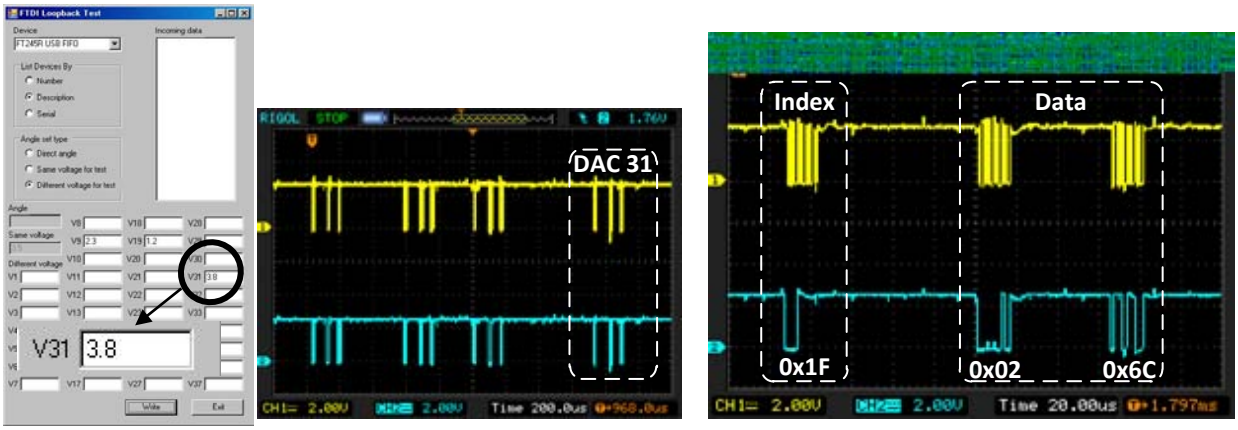


(a) (b) (c)

Figure 63 : Single voltage transmission (a) GUI, (b) all data transmission, (c) DAC 12 data transmission

Index: 0x0C => **DAC 12** ; Data: 0x023C => new value: 0x8F => $V_{DAC} = \frac{0x8F * 2 * V_{ref} * 5}{1024} = \mathbf{3.5}[V]$

Few DACs update

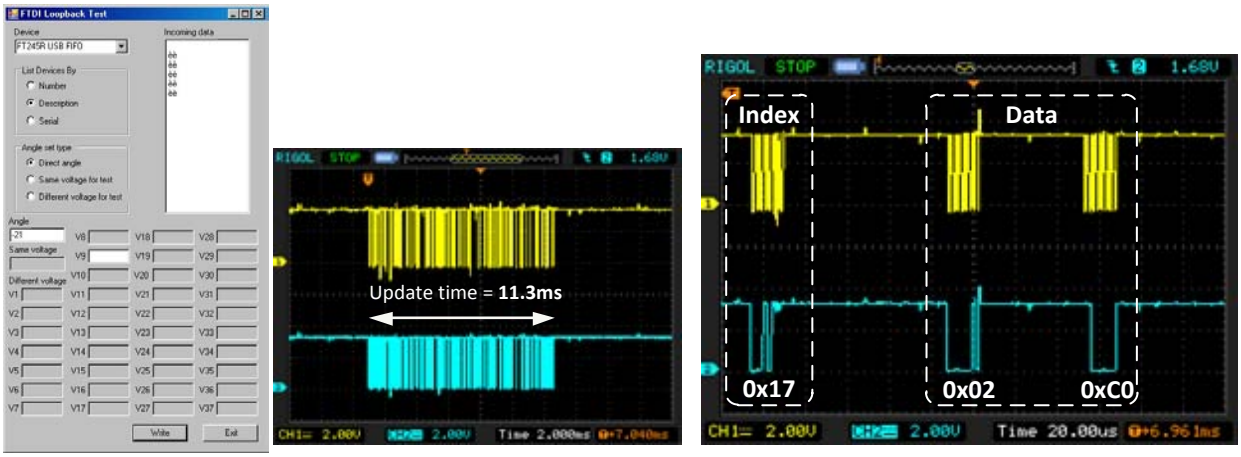


(a) (b) (c)

Figure 64 : Few voltages transmission (4 DACs) (a) GUI, (b) all data transmission, (b) DAC 31 data transmission

Index: 0x1F => **DAC 31** ; Data: 0x026C => new value: 0x9B => $V_{DAC} = \frac{0x9B * 2 * V_{ref} * 5}{1024} = 3.8[V]$

7.2.3 Direct angle



(a) (b) (c)

Figure 65: Direct angle transmission (-21°) (a) GUI, (b) all data transmission, (c) DAC24 data transmission

Index: 0x17 => **DAC 24** ; Data: 0x02C0 => new value: 0xB0 => $V_{DAC} = \frac{0xB0 * 2 * V_{ref} * 5}{1024} = 4.3[V]$

The *direct angle* transmission is more specifically tested in the section *7.3 USB-SPI Translator system*.

7.3 USB-SPI Translator system

In order to test the whole system, and at the same time the Chips selection (CPLD) function, the USB-SPI system (USB-SPI Translator and CS Dispatch boards) with the DC source board (DACs) is tested in a global experiment.

7.3.1 Tests setup

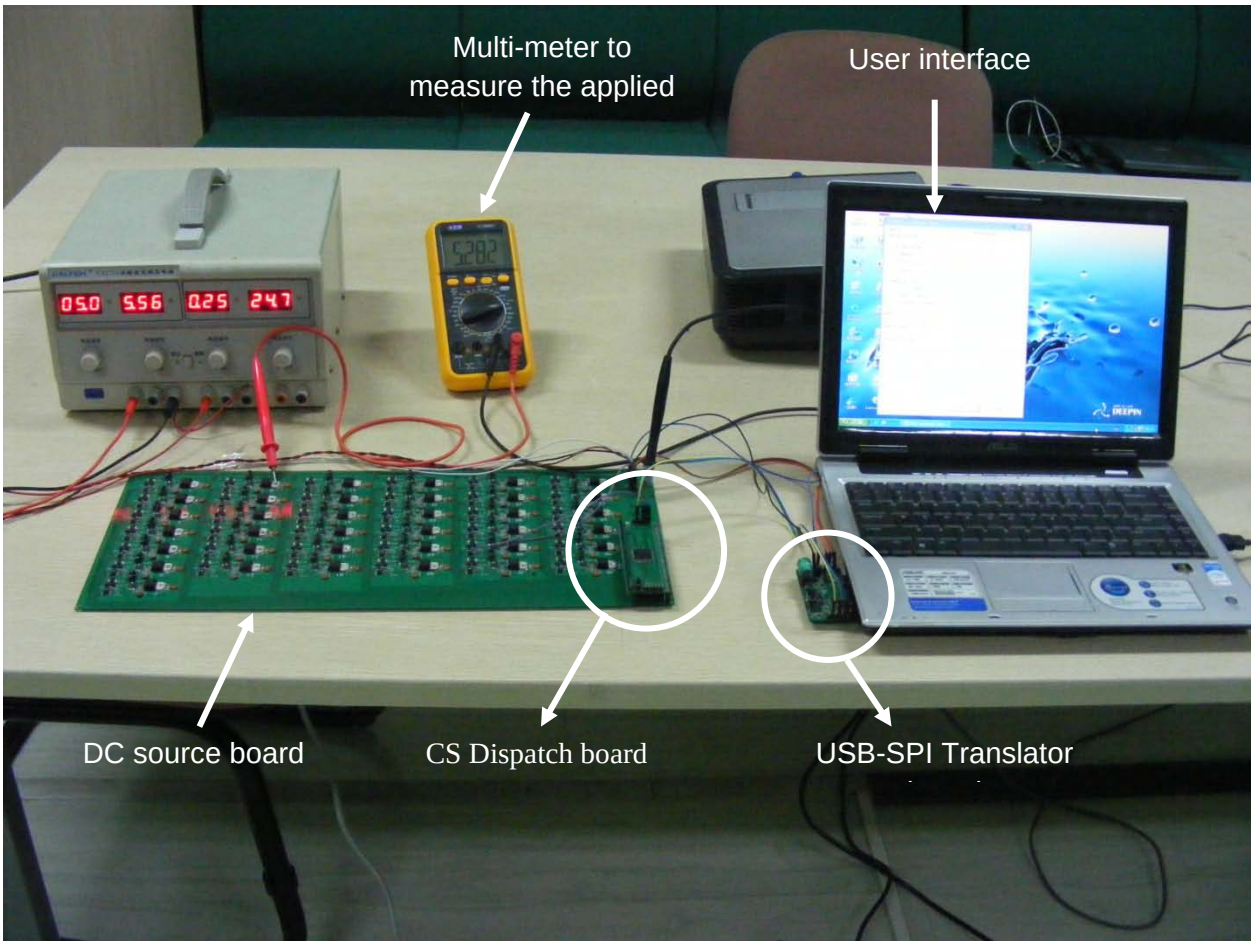


Figure 65 : Global test setup

7.3.2 DACs update

The *chips selection* function is successfully tested by using the *different voltage* type transmission. In order to completely test the USB-SPI Translator system, the *direct angle* transmission type is used. By that type of transmission every DACs should be updated with a specific value.

Two *direct angle* transmissions are tested, by measuring the DACs output the results are shown below:

Angle -21 °

DAC	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Theory	6.8	6.6	6.4	6.2	6.0	5.6	5.2	4.8	4.2	8.1	7.7	7.3	7.1	6.8	6.6	6.4	6.2	6.0
Measure	6.8	6.6	6.4	6.2	6.0	5.6	5.3	4.9	4.3	8.0	7.6	7.3	7.1	6.8	6.6	6.4	6.3	5.9

DAC	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
Theory	5.6	5.2	4.8	4.2	8.1	7.7	7.3	7.1	6.8	6.7	6.4	6.2	6.0	5.6	5.3	4.8	4.2	3.5
Measure	5.6	5.3	4.8	4.3	8.0	7.7	7.3	7.1	6.8	6.7	6.5	6.2	6.1	5.7	5.3	4.8	4.2	3.6

Angle +15 °

DAC	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18
Theory	3.5	4.0	4.5	4.9	5.2	5.5	5.8	6.0	6.2	6.3	6.5	6.6	6.7	7.0	7.1	7.3	7.5	7.8
Measure	3.6	4.1	4.5	4.9	5.2	5.5	5.9	6.0	6.3	6.3	6.4	6.6	6.7	7.0	7.1	7.3	7.6	7.7
DAC	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34	35	36
Theory	8.1	4.0	4.5	4.9	5.2	5.5	5.8	6.0	6.2	6.3	6.5	6.6	6.7	7.0	7.1	7.3	7.5	7.8
Measure	8.0	4.1	4.5	5.0	5.2	5.5	5.8	6.0	6.3	6.3	6.6	6.5	6.8	7.0	7.1	7.3	7.4	7.8

The experiment shows that the DACs are successfully updated.

7.3.3 DACs Feedback

As the DC source board has not anticipated connectors for the DACs feedback, a few wires are sold to the DACs output as shown in Figure 66. Five DACs output connected to the CS Dispatch board are enough to test the feedback processing. DAC 9, 10, 11, 12, 13 are connected.

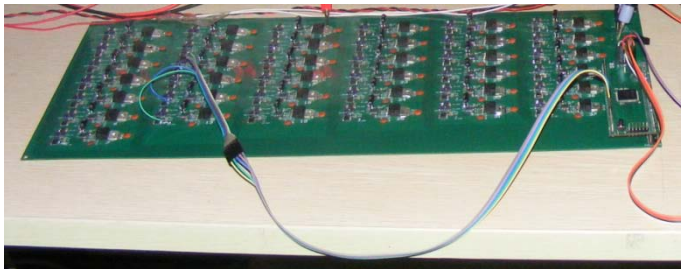


Figure 66 : DACs feedback connector

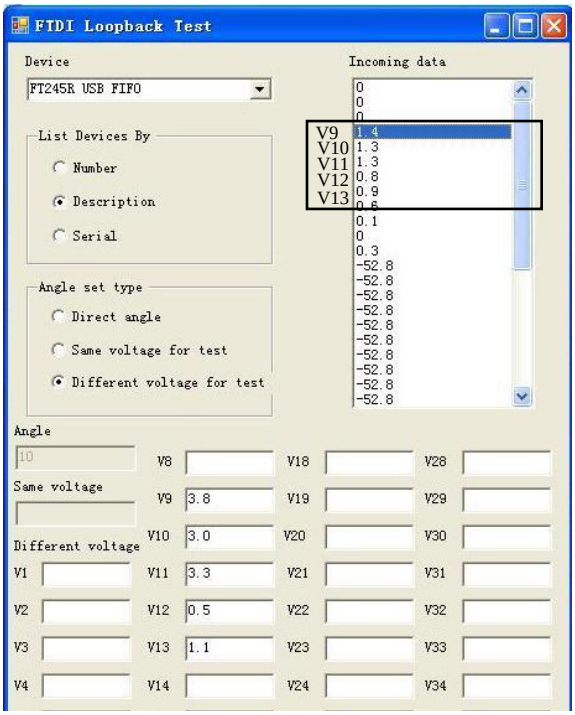


Figure 67: DACs feedback test

To test the feedback function, different values are sent to the connected DACs. The follow relation is used to check the feedback value:

$$V_{applied} = V_{feedback} * Ampli - V_{offset}$$

$$V_9 = 1.4 * 5 - 3.5 = 3.5[V]$$

$$V_{10} = 1.3 * 5 - 3.5 = 3.0[V]$$

$$V_{11} = 1.3 * 5 - 3.5 = 3.0[V]$$

$$V_{12} = 0.8 * 5 - 3.5 = 0.5[V]$$

$$V_{13} = 0.9 * 5 - 3.5 = 1.0[V]$$

The obtained results show a lack of precision, however the feedback process converts the DACs output, generate a USB data packet and sent it to the user interface which displays it. Some random value appears due to the feedback pins are not connected. The value *-52.8* stand for *no data* received. Because only five DACs are connected, not all DACs converted values are sent to the user interface.

7.4 Beam steering experiment

7.4.1 Experiment setup

The beam steering experiment is set up according to the block diagram represented in Figure 2.

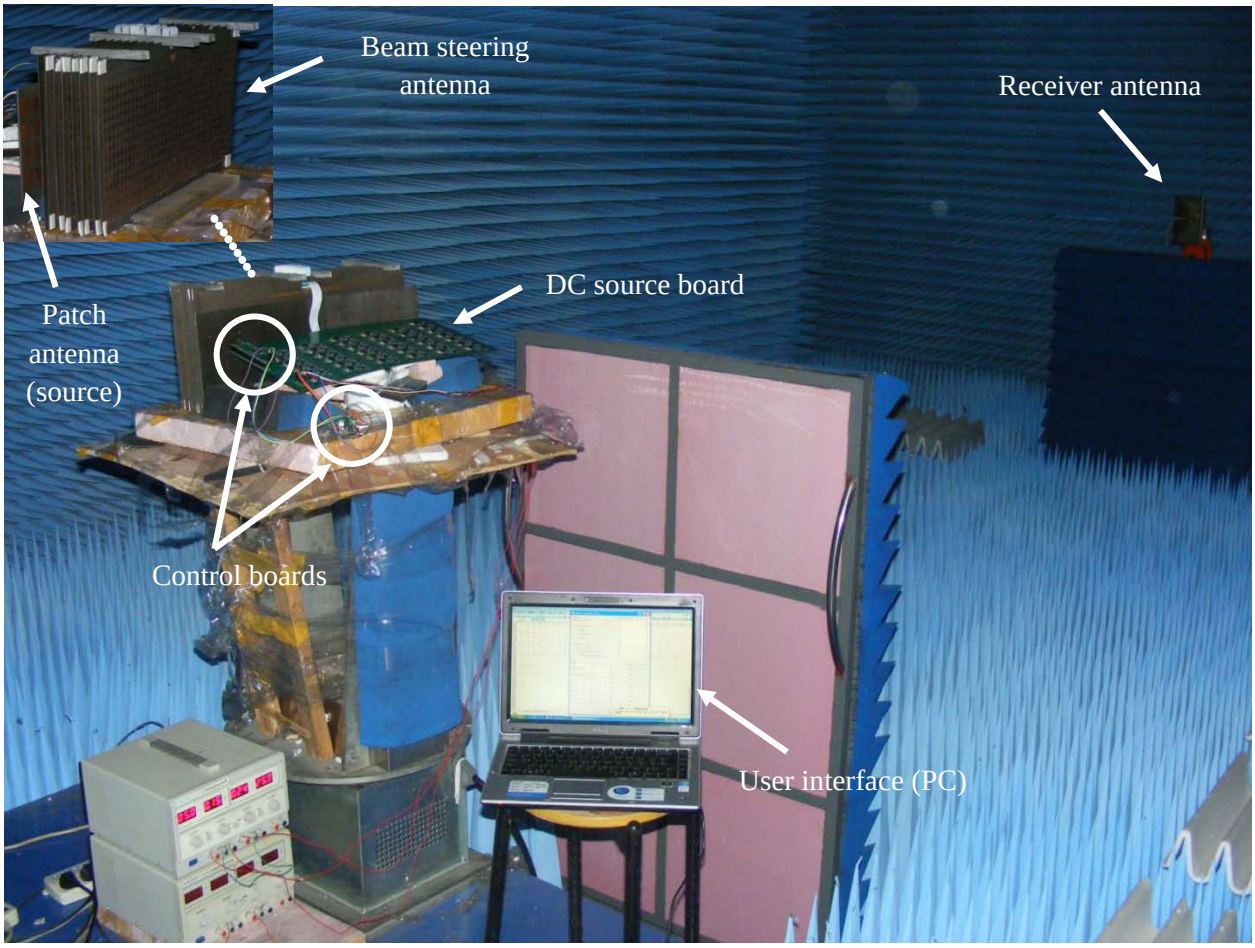


Figure 68 : Beam steering experiment setup

With the user interface, the desired angle to test is set by applying the correct voltages on the antenna (Beam steering antenna). The source signal coming from the patch antenna is deflected by the beam steering antenna in the good direction. A receiver antenna detects the source signal and stores the gain of the signal into a computer during the measurement. By rotating the antenna by 180 degrees, the gain detected by the receiver antenna varies. The maximal obtained gain represents the source antenna direction angle. The results are described in section *7.4.2 Result*.

7.4.2 Result

As mentioned above, to measure the beam angle of the source antenna, the antenna is rotated about 180 degrees while transmitting. For each rotation (1 degree steps), a computer store the gain value detected by the receiver antenna measured by a vector network analyzer. *MatLab* is used to represent the obtained gain values by the corresponding beam angle. The highest gain represents the beam angle of the source

antenna. If the set angle match with the obtained result, the transmission direction of the source antenna is correct.

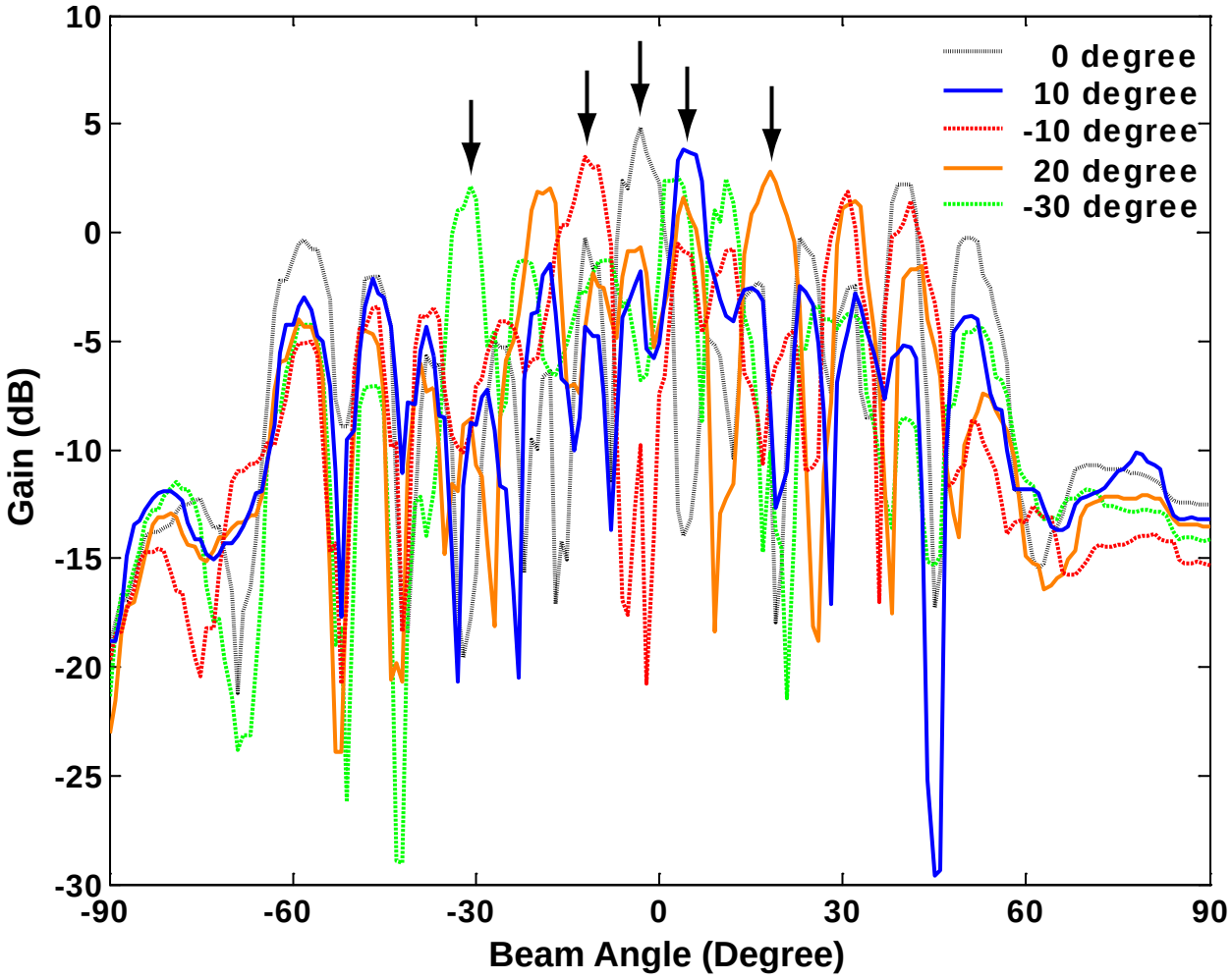


Figure 69: Beam steering experiment results

Five different angles (angle set: 0, 10, -10, 20, -30) have been tested. Figure 69 shows the five curves for the five tested angle. The five maximum gain values are pointed out with arrows. Angles 0, 10 and -10 have strong main lobe and small side lobes, and the positions of the maximum gain (main lobe) are matched well with the ones we set. The side lobes of angles 20 and -30 are little larger, but we can still recognize the main lobes with matching position. Therefore, the experiment is successful.

8 Conclusion

According to the sections 2 *Objectives* and 3 *Requirements*, a conclusion about the USB-SPI Translator system describes the status of the system and the improvements for future works.

8.1 USB-SPI Translator status

The USB-SPI Translator system is composed of two boards, *USB-SPI Translator* and *CS Dispatch*, and the graphical user interface application. For the graphical user interface, a setup file allows to install the GUI application on computers. The hardware has a final size of **16.7[mm]** by **3.6[mm]** and possesses connectors to connect the 37 DACs.

Power management

The USB-SPI Translator system is capable of selecting the power source in charge to supply the system. The first used source, if available, is the external power source. However if no external power source is available anymore, the system is self-powered by the battery. When the board is self-powered, with the experimental battery, only the data procession unit (MCU) can be supplied. The power consumption by external supply is up to **104[mA]** in active operation**.**

By low battery level detection the system is able to recharge the battery when the external power source is available.

DACs update

The USB-SPI Translator system is able to control the DC source board by using the *USB-SPI Translator* application (user interface). Once the software installed (*USB-SPI_Translator_setup.exe*) on the computer, the user has the choice between controlling the output voltage of each DAC and controlling the resulting angle of the voltage-controlled antenna.

The user can update every single DACs output voltage by choosing the *different voltage* transmission. By entering a value into the corresponding DACs input box, the user can update one, a few or every DACs. If the *same voltage* transmission is chosen, the user can update all the DACs with the same voltage at the same time.

As final purpose of the application, the user can control the resulting angle of the antenna by choosing the *direct angle* transmission. For each angle the system updates the 37 DACs output voltage in order to control the antenna direction.

An USB data packet is generated with the new voltage values according to the entered information by the user. Using the provided DLL function by *FTDI*, the USB data packet generated is sent to the USB controller (*FT245R*).

By receiving data from the computer, the USB controller starts a communication with the MCU (*ATmega88*) in order to transmit the data to the MCU by parallel operation. The received data is analyzed by the processing unit to identify the data transmission type. Each DAC is updated with the corresponding received information from the user interface. The DAC going to be updated is selected by the CPLD,

which has received the information from MCU. With the DAC selected by the CPLD, the MCU working as SPI master device sends the new digital values to the DACs (SPI slave devices).

DACs feedback processing

The MCU starts the feedback processing by informing the CPLD of a new DACs feedback processing. The CPLD selects the first DAC and the MCU execute the conversion of the first DAC output voltage. By pulling down and high the *CS* signal the next DAC is selected by the CPLD and then converted by the MCU. With all the DACs feedback information, the MCU generates an USB data packet that is sent to the USB Controller.

When data is available into the USB controller, the USB host (PC) reads the data from USB controller device and store it into a buffer. Every time new information is read from USB controller, the buffer is cleared and the new data are set in. By each end of transmission, the list box is updated with the received buffer values.

8.2 Improvements

External Clock

Currently the internal clock of the MCU is used for the data processing unit. By using an external clock generator, a more precise clock could be used to increase the analog-to-digital conversions precision. External clock generator working at high frequency would allow faster operation and thereby have faster updates of the DACs.

Battery capacity

The currently implemented battery is able to supply the data processing unit. By increasing the battery capacity the system would be better supplied and the self-powered life time increased.

Configuration

The USB data packet format allows different type of transmission. Beside the DACs update and DAC feedback transmissions, system configuration packet transmission could be implemented. By this function the user might chose to enable/disable the DAC feedback function, control the power operation mode of the system (active/sleep) and many other features.

Wireless Communication

By now a USB cable connect the computer with the USB-SPI Translator board. In order to avoid the excess of wire and the diminution of mobility, an RF communication could be implemented for the computer to USB-SPI Translator board communication.

9 References

RD [1] Diploma work specification document
RD [2] ATMEL *ATmega88 8-bit AVR Microcontroller* http://www.atmel.com
RD [3] Xilinx *XC95144XL High Performance CPLD* http://www.xilinx.com
RD [4] FTDI *FT245R USB FIFO IC* http://www.ftdichip.com
RD [5] ON Semiconductor *NCP1410 Step-Up DC/DC Converter* http://onsemi.com
RD [6] FAIRCHILD CD4011BC Quad 2-Input NAND http://www.fairchilsemi.com
RD [7] MICREL *MIC5205-3.3BM Low-Noise LDO Regulator* http://www.micrel.com
RD [8] Burr-Brown Texas Instruments *REF3020 CMOS Voltage Reference* http://www.ti.com
RD [9] FAIRCHILD *1N5227B Zener Diode* http://www.fairchildsemi.com
RD [10] Texas Instruments *TVL5606 D/A Converter* http://www.ti.com

Appendix A –Board specification

USB-SPI Translator

2010

Hes·so VALAIS WALLIS
Haute Ecole Spécialisée de Suisse occidentale
Fachhochschule Westschweiz
University of Applied Sciences Western Switzerland

Yannick Salamin

V2.0

USB-SPI Translator

[ELECTRONIC BOARD SPECIFICATION]

TABLE OF CONTENTS

1 REFERENCES

RD [1] Diploma work specification document
RD [2] FT232R_Datasheet
RD [3] MSP430_Datasheet
RD [4] USB 2.0 Specification

2 TERMS, DEFINITIONS AND ABBREVIATED TERMS

2.1 Abbreviated terms

UART	Universal asynchronous receiver transmitter
FTDI	Future Technology Devices International
SPI	Serial Peripheral Interface
MCU	Microcontroller
LED	Lighting emitting diode

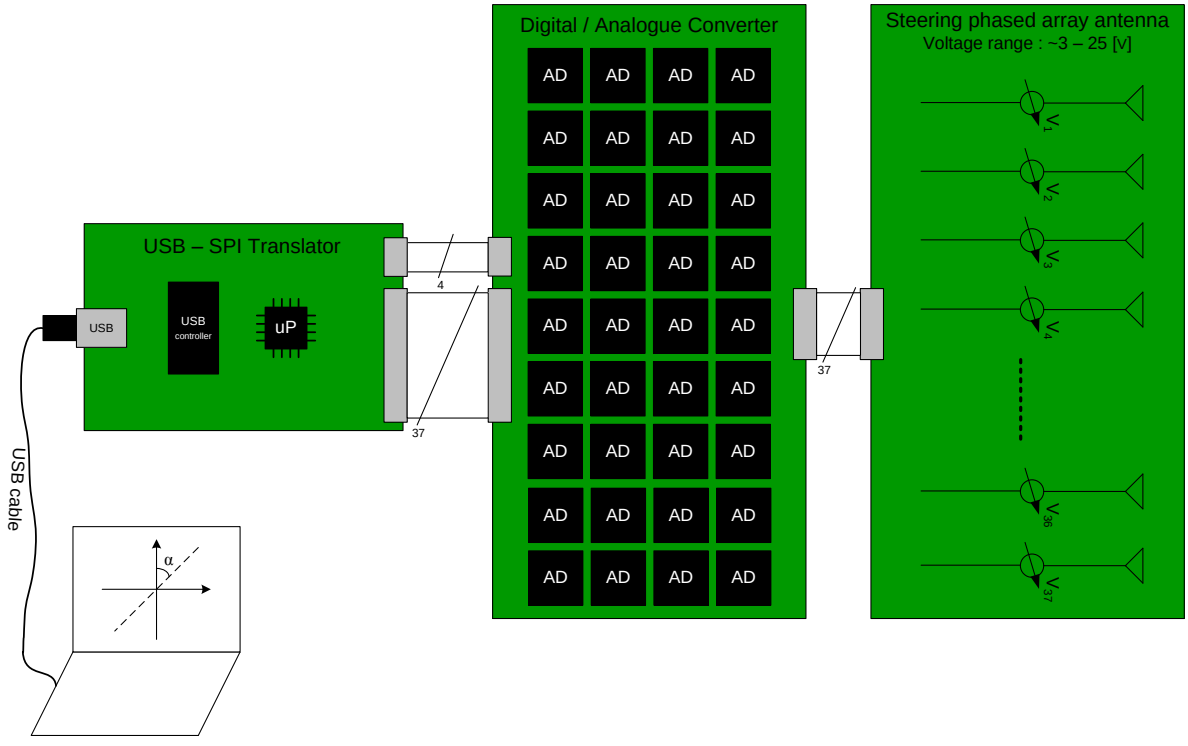
2.2 Definition

FT245R	FT245R is an USB controller which translates the USB data to serial UART interface.

3 INTRODUCTION

This document describes the specification of a USB to SPI electronic card. The specification defines what the card shall do. It will be used to design, fabricate and debug the electronic card which will be used for the USB-SPI Translator.

The purpose of this card is to translate USB data into standard SPI data and SPI data into USB data in order to manage the communication between a computer and a sub-system of a steering phased array antenna. (refer to *RD [1]).* As we need 37 chip select, the CS signal will be perform by an external board “CS_Dispach_Board”. This external board shall perform the chip selection signal for each DAC chips.



4 FUNCTIONAL SPECIFICATION

4.1 Data transfer

RQ4005: USB IF number

The card shall provide one USB link.

RQ4010: Data management

The card shall implement a USB controller FT245R and one MCU ATmega88 for data management purpose. Communication between these two components will be managed by parallel operation.

RQ4015: SPI IF number

The card shall provide two standard SPI links.

RQ4020: USB to SPI

The card shall translate received USB data packets into SPI data packets as presented in the figure below:

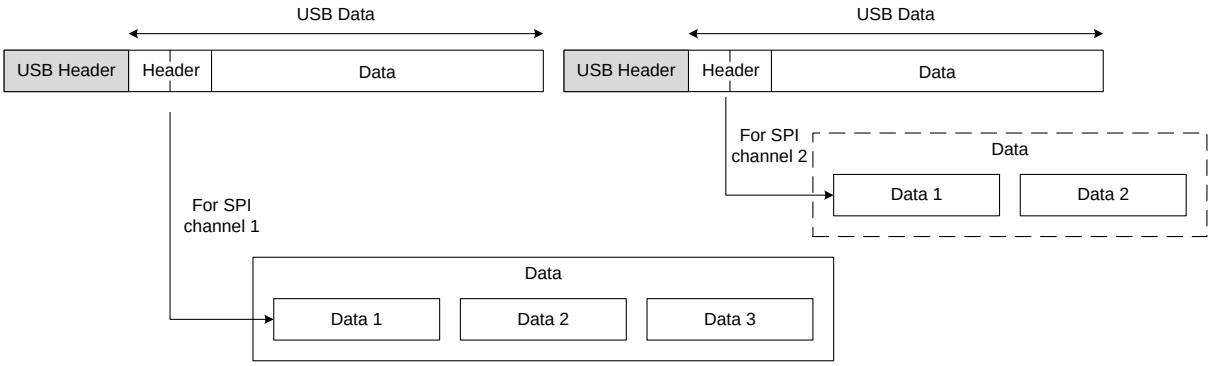


Figure 1 : USB to SPI data transmission

RQ4025: MCU - USB to SPI

Each received USB data packet is translated into one SPI packet for one SPI channel.

RQ4030: USB received data packet

The card shall manage the USB data packet coming from the computer. These packets have the following format.

SPI data transmission

Header		DATA
CMD	SPI CS	Data 1 to Data n
2 bits	6 bits	0-1022 Bytes

Figure 2 : SPI data transmission packet

CMD : 01 (SPI data transmission)

SPI CS : SPI channel selection

Data1 to Data n: Data Bytes to process

USB_SPI translator board configuration

Header		DATA
CMD	SPI CS	Data 1 to Data n
2 bits	6 bits	0-1022 Bytes

Figure 3 : USB_SPI translator board configuration packet

CMD : 10 (USB_SPI translator board)

SPI CS : SPI channel selection

Data1 to Data n: USB_SPI translator configuration data

RQ4035: SPI channel selection

The card shall select de SPI channel by using the header of the received USB data packet. The selected SPI channel shall be forward to the *CS_Dispach_Board*.

RQ4040: SPI to USB

The card shall translate the received SPI data packets into USB data packets according to the following figure:

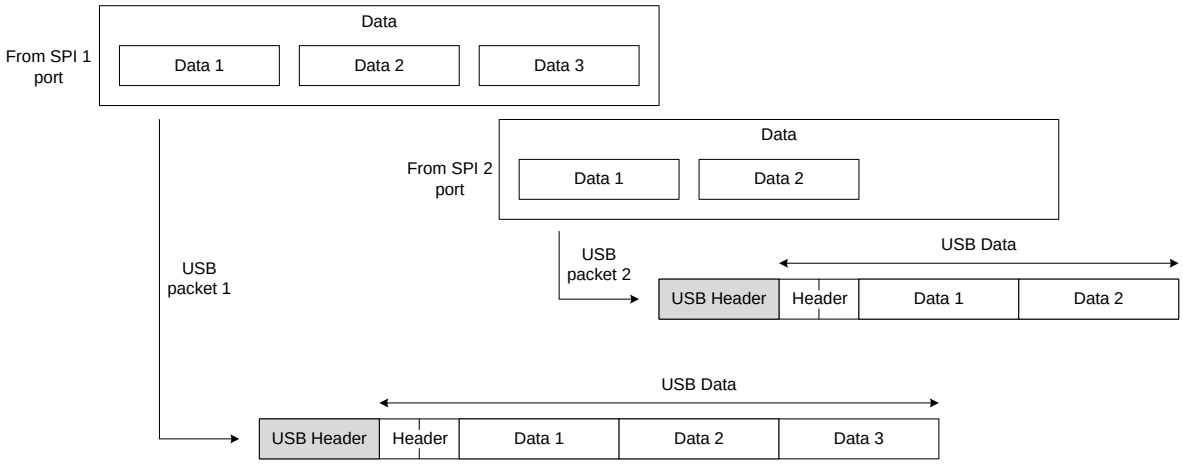


Figure 4 : SPI to USB data transmission

RQ4045: MCU - SPI to USB

The MCU shall be able to receive data from different SPI channel and to generate for each SPI channel an USB data packet that will be send to the computer.

RQ4050: USB transmitted data packet

The card shall generate USB data packets according to the following formats.

SPI data transmission

Header		DATA
Source	SPI CN	Data 1 to Data n
2 bits	6 bits	0-1022 Bytes

Figure 5 : SPI data transmission packet

Source : 01 (SPI data transmission)

SPI CN : SPI channel number

Data1 to Data n : Data Bytes from SPI port

USB_SPI translator housekeeping

Header		DATA
Source	Type	Data 1 to Data n
2 bits	6 bits	0-1022 Bytes

Figure 6 : USB_SPI translator housekeeping packet

Source : 10 (USB_SPI translator board)

Type : 000001 (status)

000010 (…)

Data1 to Data n : USB_SPI translator housekeeping data

RQ4055: MCU

The card shall implement a MCU which provide *master/slave SPI* interfaces.

4.2 Functional modes

RQ4060: system modes

The card shall provide the following modes:

“INITIALISATION”, “OPERATIONAL”, “STAND-BY”, “OFF” modes

RQ4065 : Modes transition

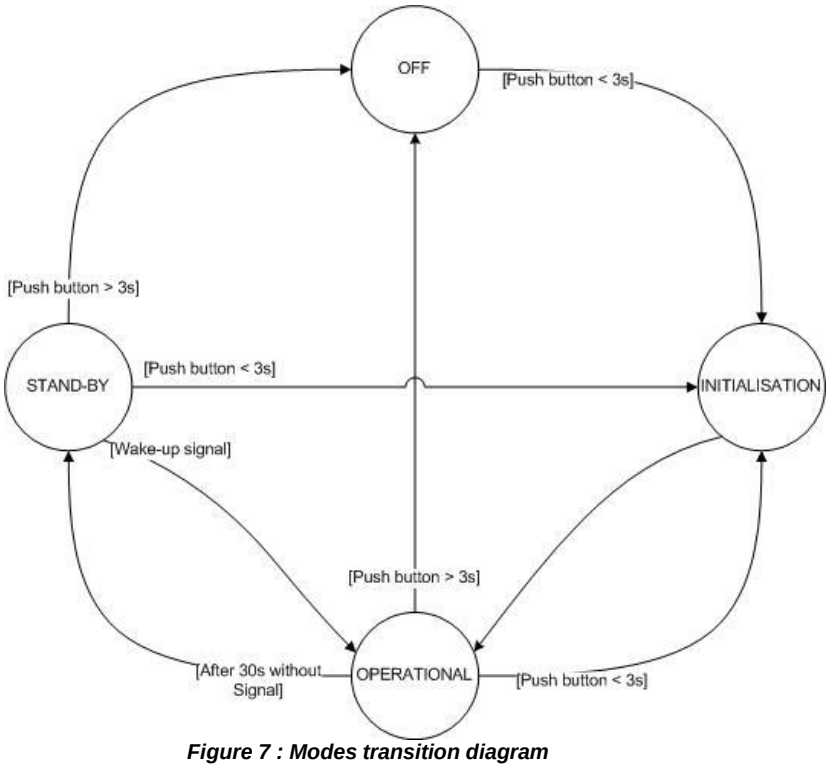


Figure 7 : Modes transition diagram

RQ4070: "OFF" mode

In this mode the whole system shall be turned off.

RQ4075: "INITIALISATION" mode

"INITIALISATION" is a switching mode from "OFF" to "OPERATIONAL" mode. This mode is automatically called after a switch on of the board.

RQ4080: "OPERATIONAL" mode

In this mode the card shall be fully operational.

RQ4085: "STAND-BY" mode

This mode will suspend the USB, so in this mode the FT245R chip and the MCU gone in suspend mode. The card will switch to the "OPERATIONAL" mode after a wake-up signal.

RQ4090: external wakeup signal

The card shall be able to wakeup according to the activity of USB and SPI interfaces. This will put the card in the "OPERATIONAL" mode (refer to *RD [4]*)

4.3 Command and housekeeping

RQ4095: Board switch on

The switch on of the board shall be realized with a push button.

RQ4100: Board reset

The card shall provide a push button in order to reset the board and to allow the initialization of all the functions.

RQ4105: Status information
The card shall provide the following status information by means of LEDS:
"POWER ON", "TRANSMITTING/RECEIVING DATA", modes status.

RQ4110: "POWER ON" information
"POWER ON" status information indicates if the card is power supplied or not. A green LED is lighting when the card is powered.

RQ4115: "TRANSMITTING/RECEIVING DATA" information
"TRANSMITTING/RECEIVING DATA" status information indicates when data is being transmitted or received by the device. A green LED is blinking when the card perform data transmission or receiving.

RQ4120: debug support
The card shall provide an interface for debug support.

5 INTERFACE

5.1 Mechanical

RQ5005: Board size
The dimensions of the board shall be.

Maximum Length: 60 mm
Maximum Width: 30 mm
Maximum Height: 20 mm

RQ5010: Board fixing
The card shall be able to be fixed to other board.

5.2 Electrical

5.2.1 POWER

RQ5015: Power plug
The card shall provide a connector which provide the power supply composed of GND and 5[V] signal.

RQ5020: Power pack
The card shall own a battery which shall be able to supply the whole board. The board shall charge the battery using the external power supply.

RQ5025: Power source
The card shall be able to select which power supply to use.

RQ5030: Voltages
The card shall be able to provide 5V and 3.3V voltage.

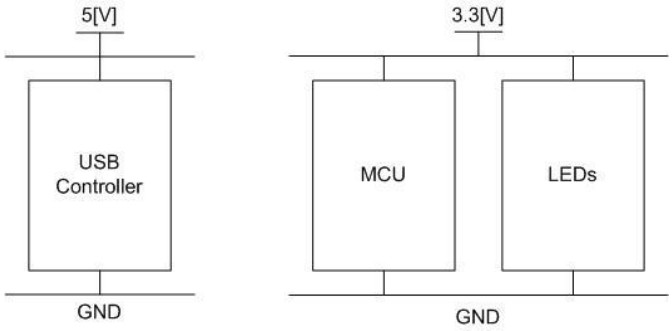


Figure 8 : Power supply

RQ5035: 3.3V voltage
The USB controller IC shall provide the 3.3V.

RQ5040: Operational mode
In operational mode the maximum current shall be 100mA.

RQ5045: Standby mode
In standby mode the maximum current shall be 500uA.

5.2.2 USB

RQ5050: USB connector
A standard USB port shall be able to connect the card to a computer *(Type*: "A" receptacle)

RQ5055: USB signals
The USB interface shall fulfill the USB1.1 / USB2.0 standards.

RQ5060: USB performance
The USB interface shall fulfill the full-speed transactions.

5.2.1 SPI

RQ5065: SPI connector
The card shall provide one standard SIP connector with 4 pins which handle the clock and the data lines for the SPI interface. Separately one SIP connector with 6 pins shall be used to transmit the selected DAC to the *CS_Dispach_Board*.

Type 1: 4 pins Male Header SIP connector
Type 2: 6 pins Male Header SIP connector

RQ5070: SPI signals
The SPI interface shall fulfill master/slave communication mode with the following connection,

4 pins Male Header SIP connector

Pin1:	*SCLK, clock signal*
Pin2:	*DIN, MOSI (Master Output Slave Input)*
Pin3:	*DOUT, MISO (Master Input Slave Output)*
Pin4:	*/FS_N, Frame synchronization*

6 pins Male Header SIP connector

Pin1: *SCLK, clock signal*

Pin2: *DIN, MOSI (Master Output Slave Input)*

Pin3: *DOUT, MISO (Master Input Slave Output)*

Pin4: *CS, chip select*

Pin5: *Feedback, analogue signal*

RQ5075: SPI master device

The card shall provide the master device who initiates the data packet.

RQ5080: SPI slave devices

Multiple slave devices are allowed with individual slave select (chip select).

5.2.2 Debug

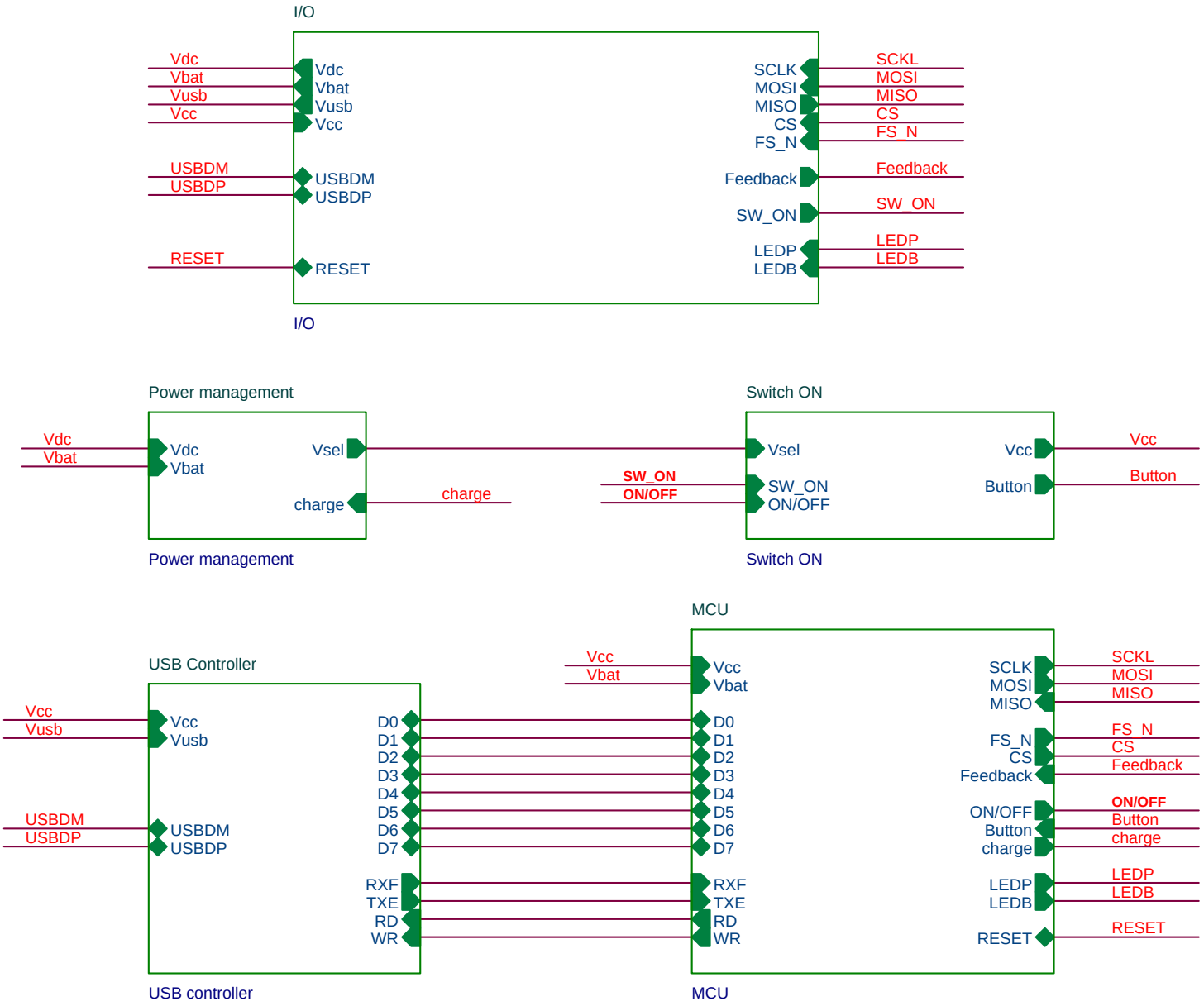
RQ5085: Debug interface

The card shall provide an interface for debug and programming the MCU.

1 pin to the MCU

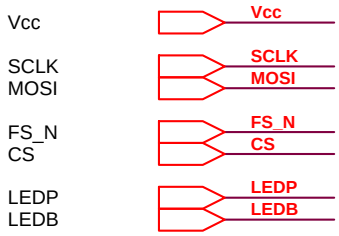
Appendix B - Schematics

USB-SPI Translator

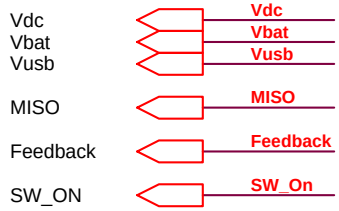


Title: USB-SPI Translator		
Size: A	Document Number: Top	Rev: V1.1
Date: Wednesday, August 25, 2010	Sheet 1 of 6	

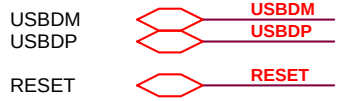
Input



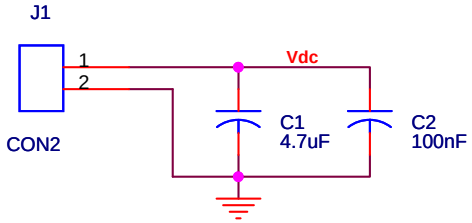
Output



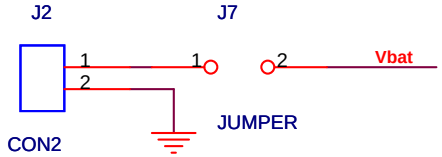
I/O



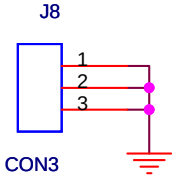
DC Connector - 5V



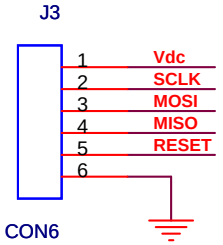
Battery Connector



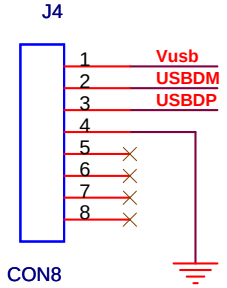
Holder



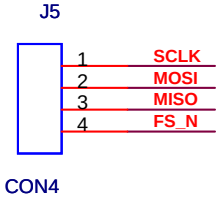
Debug Connector



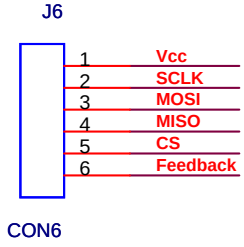
USB A Female Connector



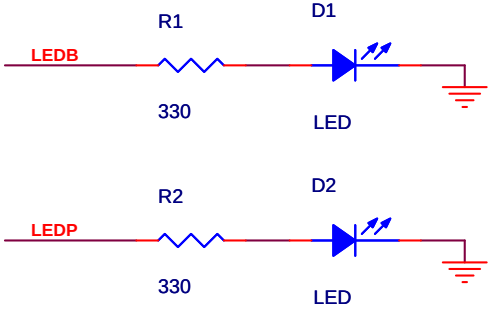
SPI Connector



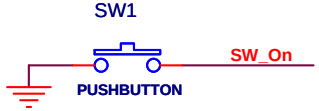
Ext. Board Connector



LEDs



Buttons



Title	USB-SPI Translator	
Size A	Document Number I/O	Rev V1.1
Date: Wednesday, August 25, 2010	Sheet 2 of 6	

Input

Vdc
Vbat

Vdc
Vbat

charge

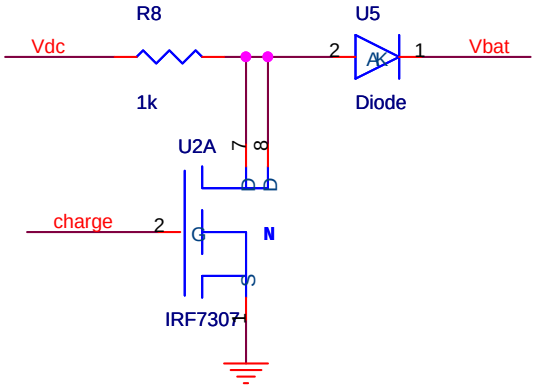
charge

Output

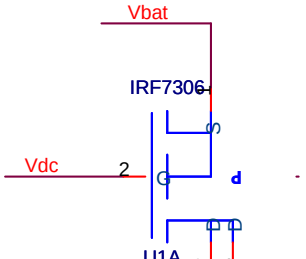
Vsel

Vsel

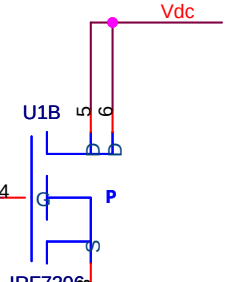
Battery charger



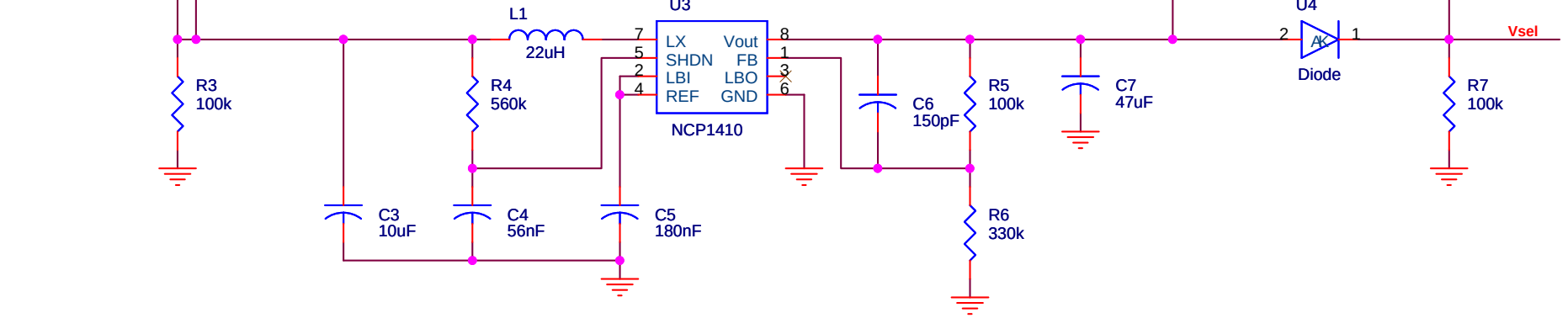
Battery control



Power selector

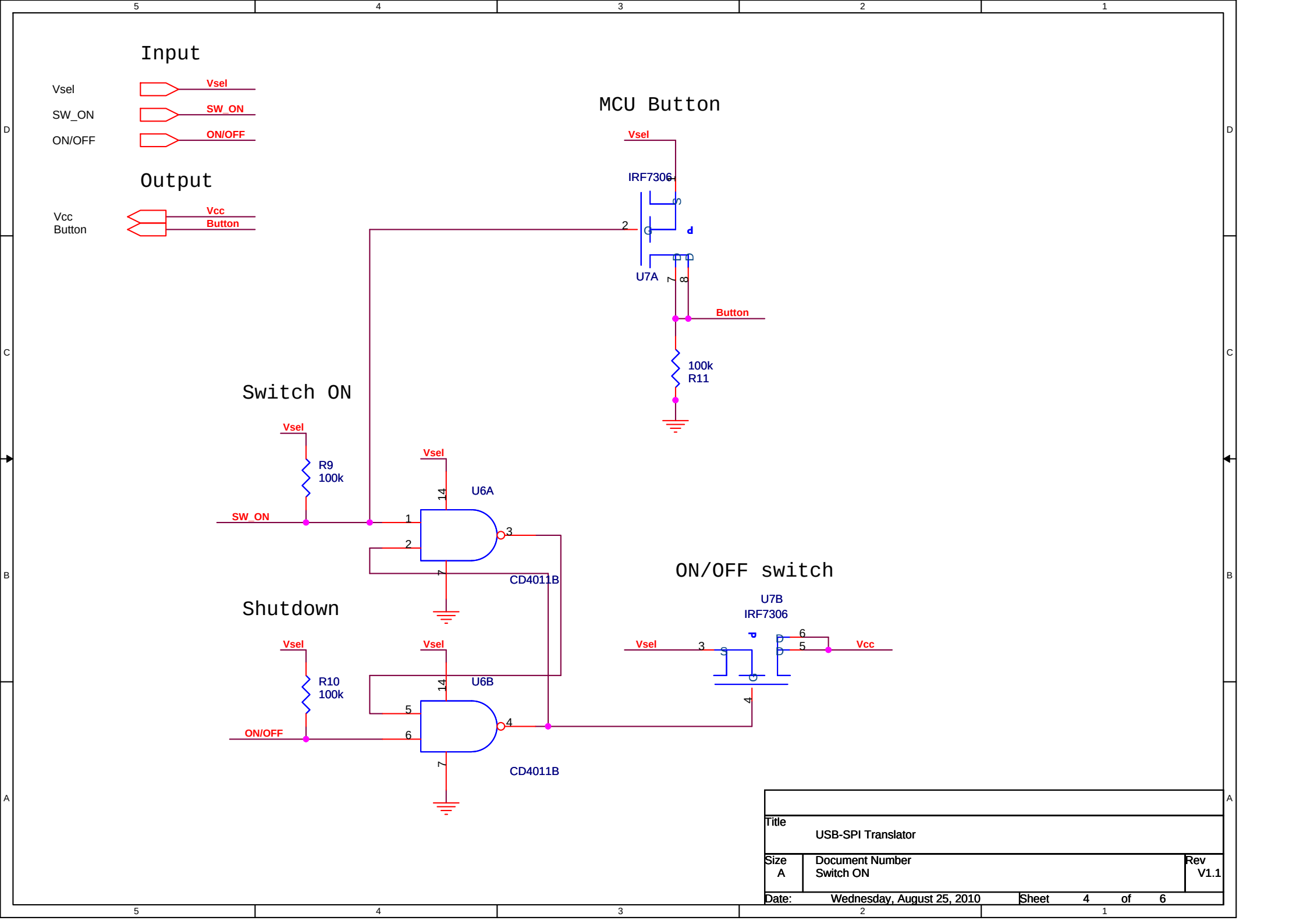


Step-up - 5V



Vout(Step-up) = 1.19 * (1+R5/R6)

Title	USB-SPI Translator	
Size A	Document Number Power management	Rev V1.1
Date: Wednesday, August 25, 2010	Sheet 3 of 6	


Input
Vsel
SW_ON
ON/OFF
Output
Vcc
Button
MCU Button
IRF7306
U7A
100k
R11
Switch ON
R9
100k
U6A
CD4011B
ON/OFF switch
U7B
IRF7306
Shutdown
R10
100k
U6B
CD4011B
Title
USB-SPI Translator
Size
A
Document Number
Switch ON
Rev
V1.1
Date:
Wednesday, August 25, 2010
Sheet
4
of
6

Input

Vcc
Vusb

RD
WR

Output

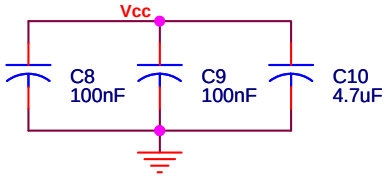
RXF
TXE

I/O

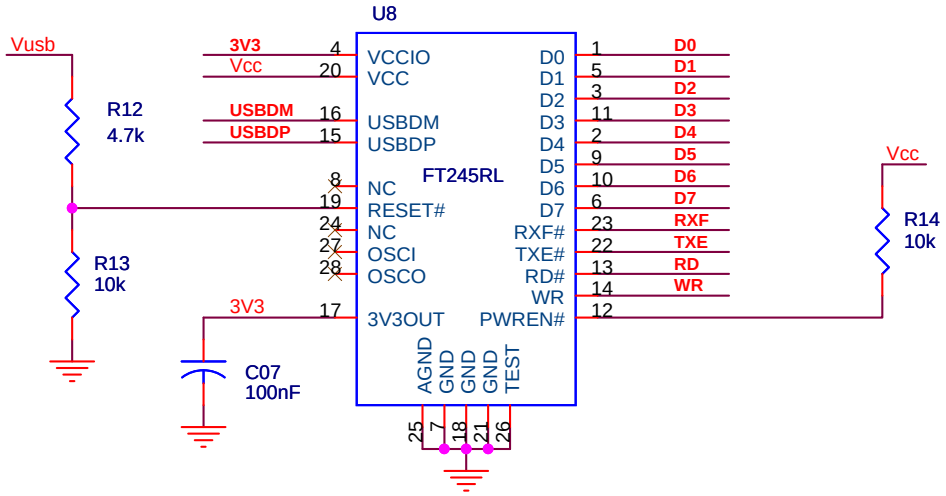
USBDM
USBDP

D0
D1
D2
D3
D4
D5
D6
D7

Decoupling



USB Controller



Title: USB-SPI Tranlator		
Size: A	Document Number: USB Controller	Rev: V1.1
Date: Wednesday, August 25, 2010	Sheet 5 of 6	

INPUT

Vcc
Vbat

MISO
Feedback

Button

RXF
TXE

OUTPUT

SCLK
MOSI
CS
FS_N

ON/OFF
charge

LEDP
LEDB

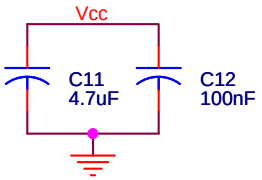
RD
WR

I/O

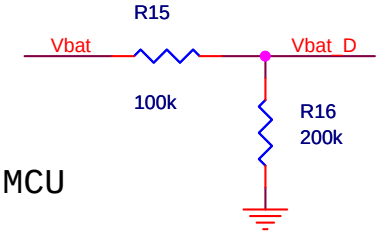
RESET

D0
D1
D2
D3
D4
D5
D6
D7

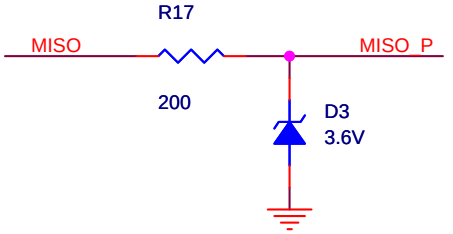
Decoupling



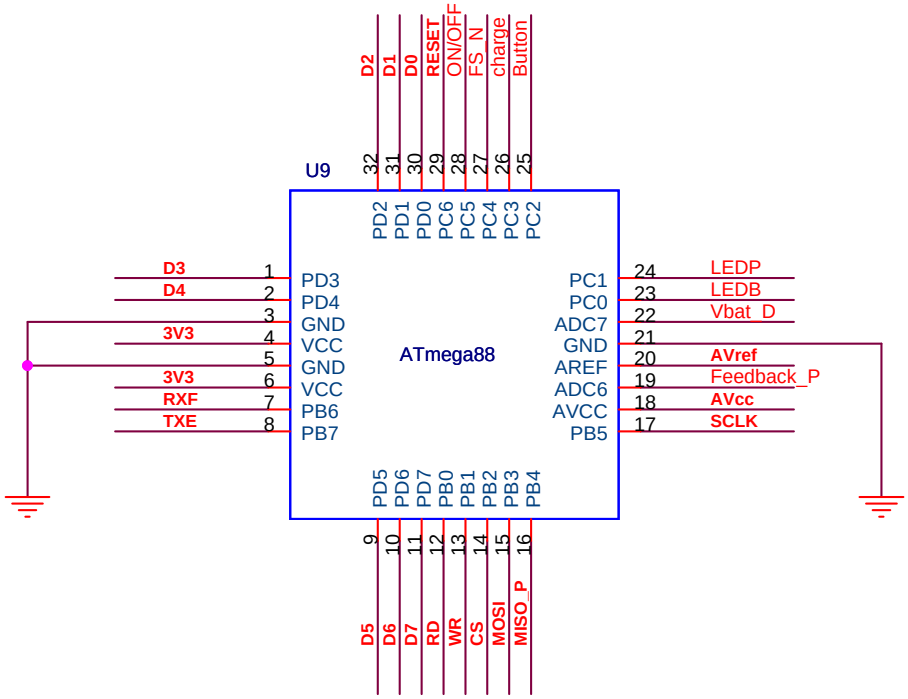
Vbat divider for ADC



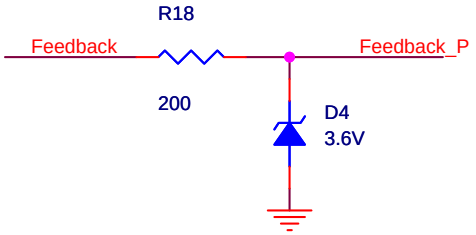
Digital input protection



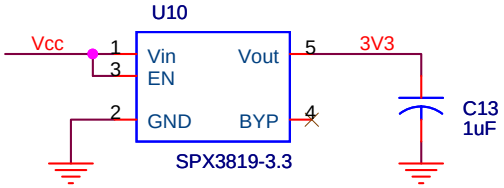
MCU



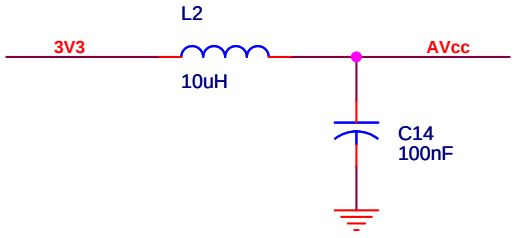
Analogue input protection



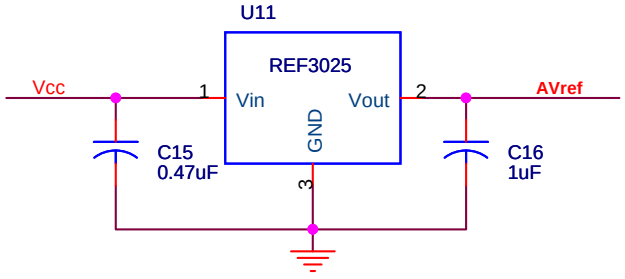
Voltage regulator - 3.3V



LC filter

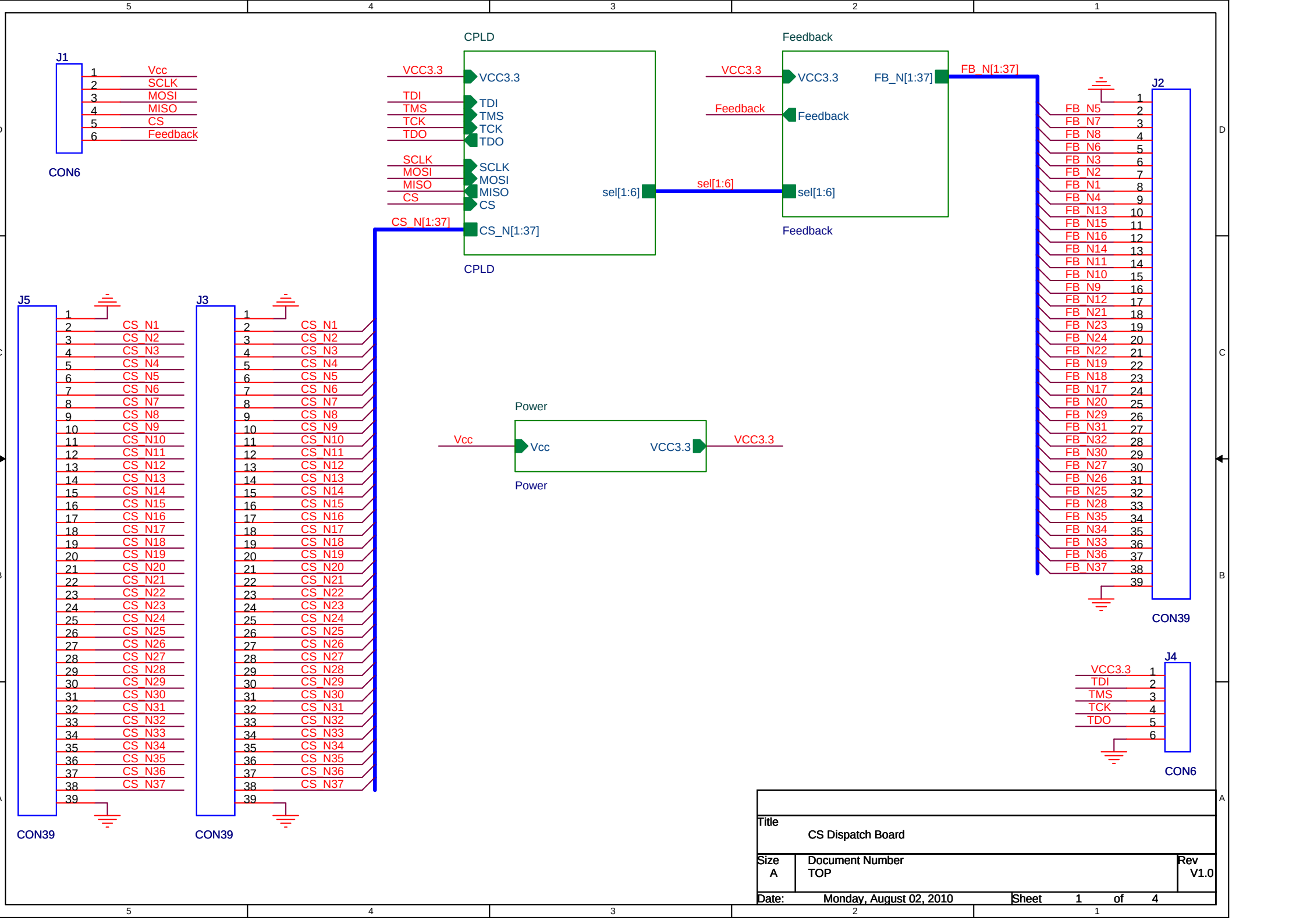


Voltage regulator - 2.5V



Title: USB-SPI Translator		
Size: A	Document Number: MCU	Rev: V1.1
Date: Sunday, September 12, 2010	Sheet 6 of 6	

CS Dispatch


J1
1 Vcc
2 SCLK
3 MOSI
4 MISO
5 CS
6 Feedback
CON6
CPLD
VCC3.3
TDI
TMS
TCK
TDO
SCLK
MOSI
MISO
CS
CS_N[1:37]
sel[1:6]
CS_N[1:37]
CPLD
Feedback
VCC3.3
Feedback
FB_N[1:37]
sel[1:6]
Feedback
J2
FB_N5 2
FB_N7 3
FB_N8 4
FB_N6 5
FB_N3 6
FB_N2 7
FB_N1 8
FB_N4 9
FB_N13 10
FB_N15 11
FB_N16 12
FB_N14 13
FB_N11 14
FB_N10 15
FB_N9 16
FB_N12 17
FB_N21 18
FB_N23 19
FB_N24 20
FB_N22 21
FB_N19 22
FB_N18 23
FB_N17 24
FB_N20 25
FB_N29 26
FB_N31 27
FB_N32 28
FB_N30 29
FB_N27 30
FB_N26 31
FB_N25 32
FB_N28 33
FB_N35 34
FB_N34 35
FB_N33 36
FB_N36 37
FB_N37 38
39
CON39
Power
Vcc
Vcc
VCC3.3
VCC3.3
Power
J5
CS_N1 2
CS_N2 3
CS_N3 4
CS_N4 5
CS_N5 6
CS_N6 7
CS_N7 8
CS_N8 9
CS_N9 10
CS_N10 11
CS_N11 12
CS_N12 13
CS_N13 14
CS_N14 15
CS_N15 16
CS_N16 17
CS_N17 18
CS_N18 19
CS_N19 20
CS_N20 21
CS_N21 22
CS_N22 23
CS_N23 24
CS_N24 25
CS_N25 26
CS_N26 27
CS_N27 28
CS_N28 29
CS_N29 30
CS_N30 31
CS_N31 32
CS_N32 33
CS_N33 34
CS_N34 35
CS_N35 36
CS_N36 37
CS_N37 38
39
CON39
J3
CS_N1 2
CS_N2 3
CS_N3 4
CS_N4 5
CS_N5 6
CS_N6 7
CS_N7 8
CS_N8 9
CS_N9 10
CS_N10 11
CS_N11 12
CS_N12 13
CS_N13 14
CS_N14 15
CS_N15 16
CS_N16 17
CS_N17 18
CS_N18 19
CS_N19 20
CS_N20 21
CS_N21 22
CS_N22 23
CS_N23 24
CS_N24 25
CS_N25 26
CS_N26 27
CS_N27 28
CS_N28 29
CS_N29 30
CS_N30 31
CS_N31 32
CS_N32 33
CS_N33 34
CS_N34 35
CS_N35 36
CS_N36 37
CS_N37 38
39
CON39
J4
VCC3.3 1
TDI 2
TMS 3
TCK 4
TDO 5
6
CON6
Title
CS Dispatch Board
Size
A
Document Number
TOP
Rev
V1.0
Date: Monday, August 02, 2010
Sheet 1 of 4

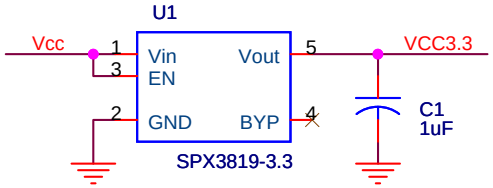
Inputs

Vcc

Outputs

VCC3.3

Voltage regulator - 3.3V



Title	CS Dispatch Board	
Size A	Document Number Power	Rev V1.0
Date: Monday, August 02, 2010	Sheet 2 of 4	

CPLD

Inputs

VCC3.3 → VCC3.3

TDI → TDI
TMS → TMS
TCK → TCK

SCLK → SCLK
MOSI → MOSI
CS → CS

Outputs

TDO → TDO

MISO → MISO

CS_N[1:37]

CS_N1, CS_N2, CS_N3, CS_N4, CS_N5, CS_N6, CS_N7, CS_N8, CS_N9, CS_N10, CS_N11, CS_N12, CS_N13, CS_N14, CS_N15, CS_N16, CS_N17, CS_N18, CS_N19, CS_N20, CS_N21, CS_N22, CS_N23, CS_N24, CS_N25, CS_N26, CS_N27, CS_N28, CS_N29, CS_N30, CS_N31, CS_N32, CS_N33, CS_N34, CS_N35, CS_N36, CS_N37

sel[1:6]

sel1, sel2, sel3, sel4, sel5, sel6

U2 — XC95144XL

VCC3.3	5	VCCINT	
	57	VCCINT	
	98	VCCINT	
	26	VCCIO	
	38	VCCIO	
	51	VCCIO	
	88	VCCIO	
TCK	48	TCK	
TDI	45	TDI	
TDO	83	TDO	
TMS	47	TMS	
SCLK	22	GCK1	
	23	GCK2	
GND	27	GCK3	
MOSI	6	I/O	
MISO	7	I/O	
CS	8	I/O	
LEDP	9	I/O	
LEDC	10	I/O	
sel1	11	I/O	
sel2	12	I/O	
sel3	13	I/O	
sel4	14	I/O	
sel5	15	I/O	
sel6	16	I/O	
	17	I/O	
	18	I/O	
	19	I/O	
	20	I/O	
	24	I/O	
	25	I/O	
	28	I/O	
	29	I/O	
	30	I/O	
	32	I/O	
	33	I/O	
	34	I/O	
	87	I/O	
	89	I/O	
	90	I/O	
	91	I/O	
	92	I/O	
	93	I/O	
	94	I/O	
	95	I/O	
	96	I/O	
	97	I/O	
GND	21	GND	
GND	31	GND	
GND	44	GND	
GND	62	GND	
GND	69	GND	
GND	75	GND	
GND	84	GND	
GND	100	GND	
	3	GTS1	
	4	GTS2	
	1	GTS3	
GND	2	GTS4	
RESET	99	GSR	
CS_N1	35	I/O	
CS_N2	36	I/O	
CS_N3	37	I/O	
CS_N4	39	I/O	
CS_N5	40	I/O	
CS_N6	41	I/O	
CS_N7	42	I/O	
CS_N8	43	I/O	
GND	46	I/O	
CS_N9	49	I/O	
CS_N30	74	I/O	
CS_N31	76	I/O	
CS_N32	77	I/O	
CS_N33	78	I/O	
CS_N34	79	I/O	
CS_N35	80	I/O	
CS_N36	81	I/O	
CS_N37	82	I/O	
	85	I/O	
GND	86	I/O	
CS_N10	50	I/O	
CS_N11	52	I/O	
CS_N12	53	I/O	
CS_N13	54	I/O	
CS_N14	55	I/O	
CS_N15	56	I/O	
CS_N16	58	I/O	
CS_N17	59	I/O	
CS_N18	60	I/O	
CS_N19	61	I/O	
CS_N20	63	I/O	
CS_N21	64	I/O	
CS_N22	65	I/O	
CS_N23	66	I/O	
CS_N24	67	I/O	
CS_N25	68	I/O	
CS_N26	70	I/O	
CS_N27	71	I/O	
CS_N28	72	I/O	
CS_N29	73	I/O	

Push button - RESET

SW1 (PUSHBUTTON) — R3 (1k) — VCC3.3

RESET

LED - Power/Communication

LEDP → R1 (330) → D1 (LED)

LEDC → R2 (330) → D2 (LED)

Decoupling

VCC3.3

C2 0.1uF, C3 0.1uF, C4 0.1uF, C5 0.1uF, C6 0.1uF, C7 0.1uF, C8 0.1uF

Ground

GND

Title	CS Dispatch Board		
Size A	Document Number CPLD		Rev V1.0
Date: Monday, August 02, 2010		Sheet 3 of 4	

Multiplexers

Inputs

VCC3.3 → VCC3.3

FB_N[1:37] → FB_N1, FB_N2, FB_N3, FB_N4, FB_N5, FB_N6, FB_N7, FB_N8, FB_N9, FB_N10, FB_N11, FB_N12, FB_N13, FB_N14, FB_N15, FB_N16, FB_N17, FB_N18, FB_N19, FB_N20, FB_N21, FB_N22, FB_N23, FB_N24, FB_N25, FB_N26, FB_N27, FB_N28, FB_N29, FB_N30, FB_N31, FB_N32, FB_N33, FB_N34, FB_N35, FB_N36, FB_N37

sel[1:6] → sel1, sel2, sel3, sel4, sel5, sel6

Outputs

Feedback → Feedback

U3 — SN74HC4851

Pin	Signal
16	VCC3.3
13	FB_N1
14	FB_N2
15	FB_N3
12	FB_N4
1	FB_N5
5	FB_N6
2	FB_N7
4	FB_N8
3	COM
11	A = sel1
10	B = sel2
9	C = sel3
6	INH
7	NC
8	GND

U4 — SN74HC4851

Pin	Signal
16	VCC3.3
13	FB_N9
14	FB_N10
15	FB_N11
12	FB_N12
1	FB_N13
5	FB_N14
2	FB_N15
4	FB_N16
3	COM
11	A = sel1
10	B = sel2
9	C = sel3
6	INH
7	NC
8	GND

U5 — SN74HC4851

Pin	Signal
16	VCC3.3
13	FB_N17
14	FB_N18
15	FB_N19
12	FB_N20
1	FB_N21
5	FB_N22
2	FB_N23
4	FB_N24
3	COM
11	A = sel1
10	B = sel2
9	C = sel3
6	INH
7	NC
8	GND

U6 — SN74HC4851

Pin	Signal
16	VCC3.3
13	FB_N25
14	FB_N26
15	FB_N27
12	FB_N28
1	FB_N29
5	FB_N30
2	FB_N31
4	FB_N32
3	COM
11	A = sel1
10	B = sel2
9	C = sel3
6	INH
7	NC
8	GND

U7 — SN74HC4851

Pin	Signal
16	VCC3.3
13	FB_N33
14	FB_N34
15	FB_N35
12	FB_N36
1	FB_N37
5	
2	
4	
3	COM
11	A = sel1
10	B = sel2
9	C = sel3
6	INH
7	NC
8	GND

U8 — SN74HC4851

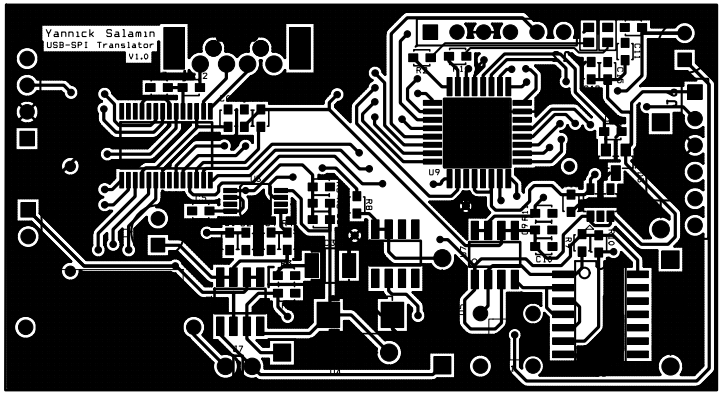
Pin	Signal
16	VCC3.3
13	Y0
14	Y1
15	Y2
12	Y3
1	Y4
5	Y5
2	Y6
4	Y7
3	COM = Feedback
11	A = sel4
10	B = sel5
9	C = sel6
6	INH
7	NC
8	GND

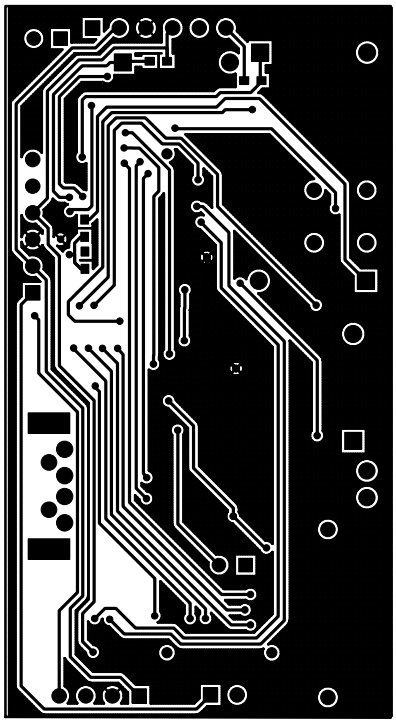
VCC3.3 → C9 32pF, C10 32pF, C11 32pF, C12 32pF, C13 32pF, C14 32pF

Title	CS Dispatch Board	
Size A	Document Number Feedback	Rev V1.0
Date: Monday, August 02, 2010	Sheet 4 of 4	

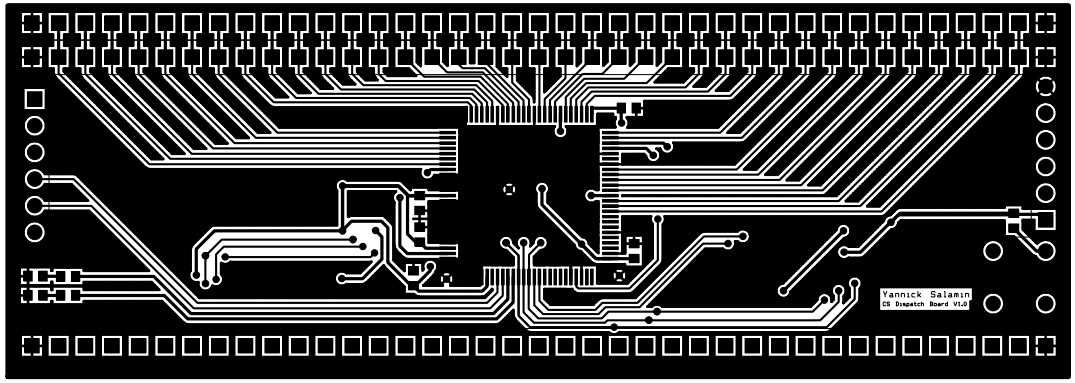
Appendix C – PCB Layouts

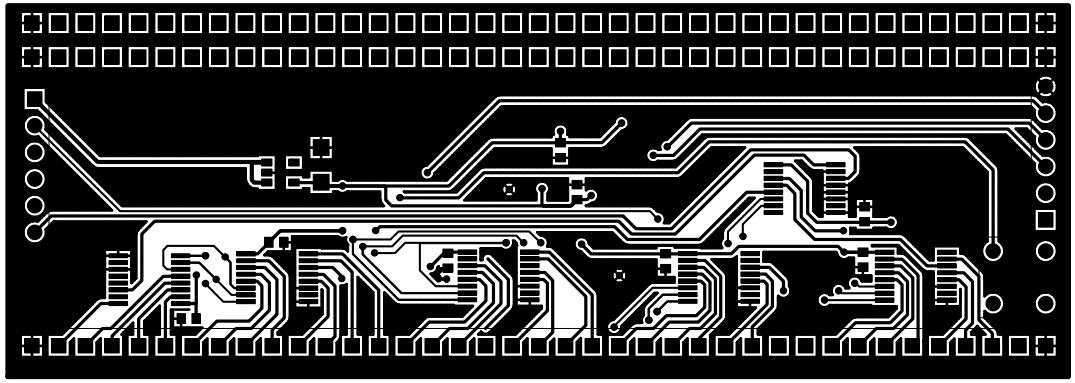
USB-SPI Translator


Yannick Salamin
USB-SPI Translator
V1.0



CS Dispatch


Yannick Salamin
CS Dispatch Board V1.0



Appendix D – Bill of Materials

USB-SPI Translator

USB-SPI Translator Revised: Wednesday, August 25, 2010
Top Revision: V1.1

Bill Of Materials September 12,2010 9:51:43 Page1

Item	Quantity	Reference		Part
1	3	C1,C10,C11		4.7uF
2	6	C2,C07,C8,C9,C12,C14	100nF	
3	1	C3		10uF
4	1	C4		56nF
5	1	C5		180nF
6	1	C6		150pF
7	1	C7		47uF
8	2	C13,C16	1uF	
9	1	C15		0.47uF
10	2	D1,D2		LED
11	2	D3,D4		3.6V
12	2	J1,J2		CON2
13	2	J3,J6		CON6
14	1	J4		CON8
15	1	J5		CON4
16	1	J7		JUMPER
17	1	J8		CON3
18	1	L1		22uH
19	1	L2		10uH
20	2	R1,R2		330
21	7	R3,R5,R7,R9,R10,R11,R15		100k
22	1	R4		560k
23	1	R6		330k
24	1	R8		1k
25	1	R12		4.7k
26	2	R13,R14	10k	
27	1	R16		200k
28	2	R17,R18	200	
29	1	SW1		PUSHBUTTON
30	2	U1,U7		IRF7306
31	1	U2		IRF7307
32	1	U3		NCP1410
33	2	U4,U5		Diode
34	1	U6		CD4011B
35	1	U8		FT245RL
36	1	U9		ATmega88
37	1	U10		SPX3819-3.3
38	1	U11		REF3025

CS Dispatch

CS Dispatch Board Revised: Tuesday, August 03, 2010
TOP Revision: V1.0

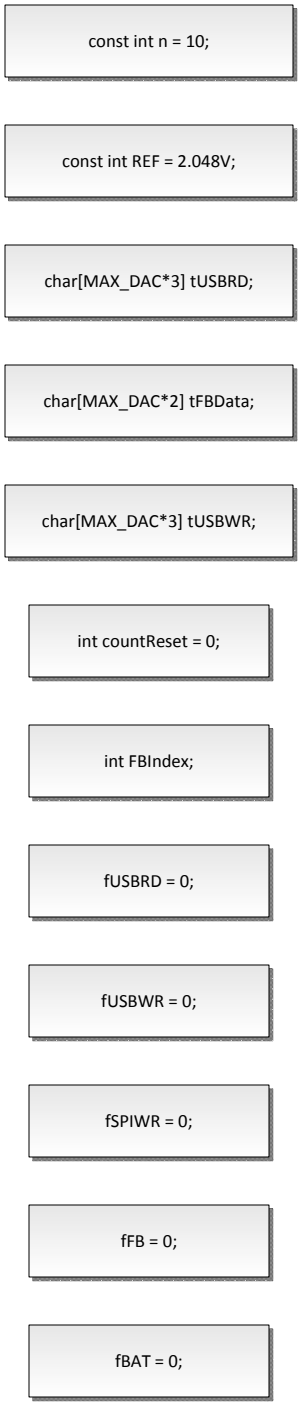
Bill Of Materials September 12,2010 9:54:39 Page1

Item	Quantity	Reference	Part
1	1	C1	1uF
2	7	C2,C3,C4,C5,C6,C7,C8	0.1uF
3	6	C9,C10,C11,C12,C13,C14	32pF
4	2	D1,D2	LED
5	2	J1,J4	CON6
6	3	J2,J3,J5	CON39
7	2	R1,R2	330
8	1	R3	1k
9	1	SW1	PUSHBUTTON
10	1	U1	SPX3819-3.3
11	1	U2	XC95144XL
12	6	U3,U4,U5,U6,U7,U8	SN74HC4851

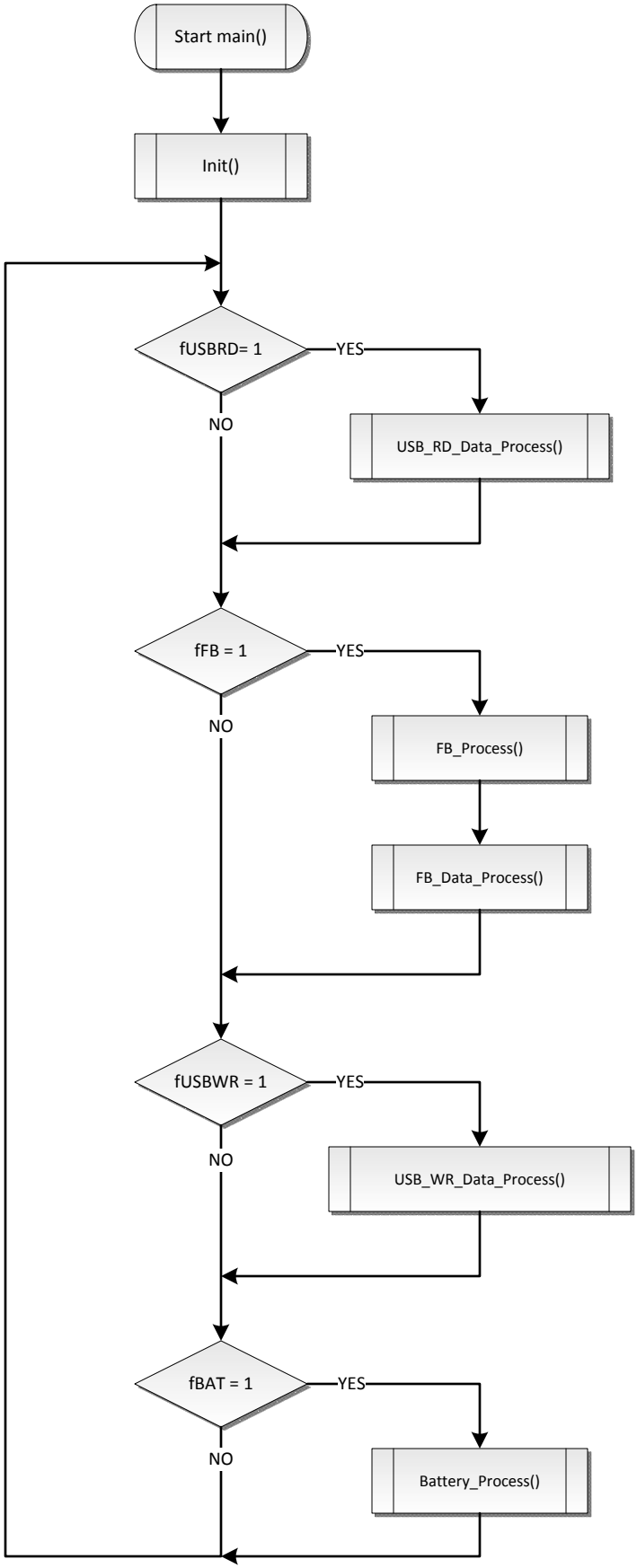
Appendix E – Source code

USB-SPI Translator

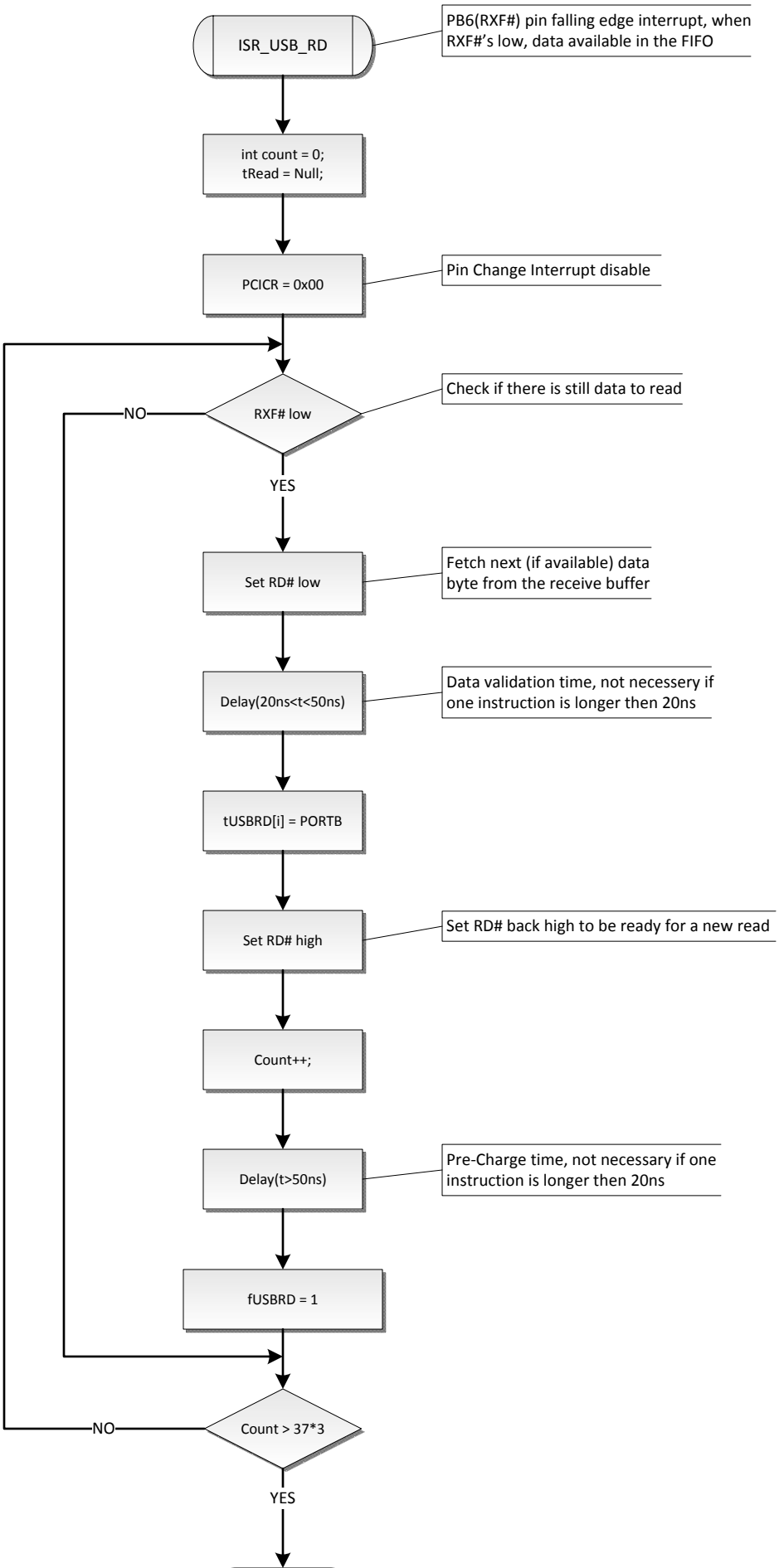
Global definitions

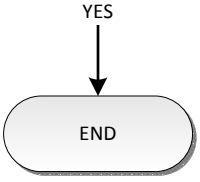


Main function

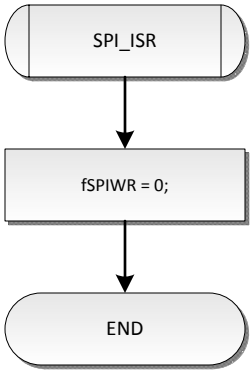


USB Read Interrupt Sub Routine

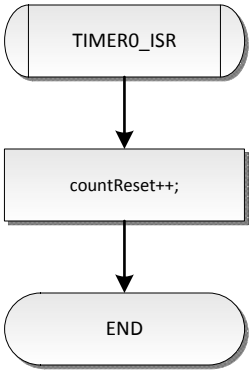



YES
END

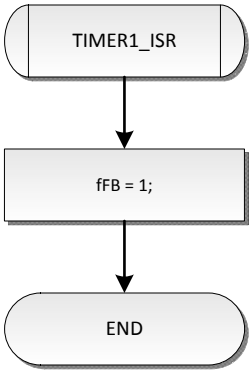
SPI ISR



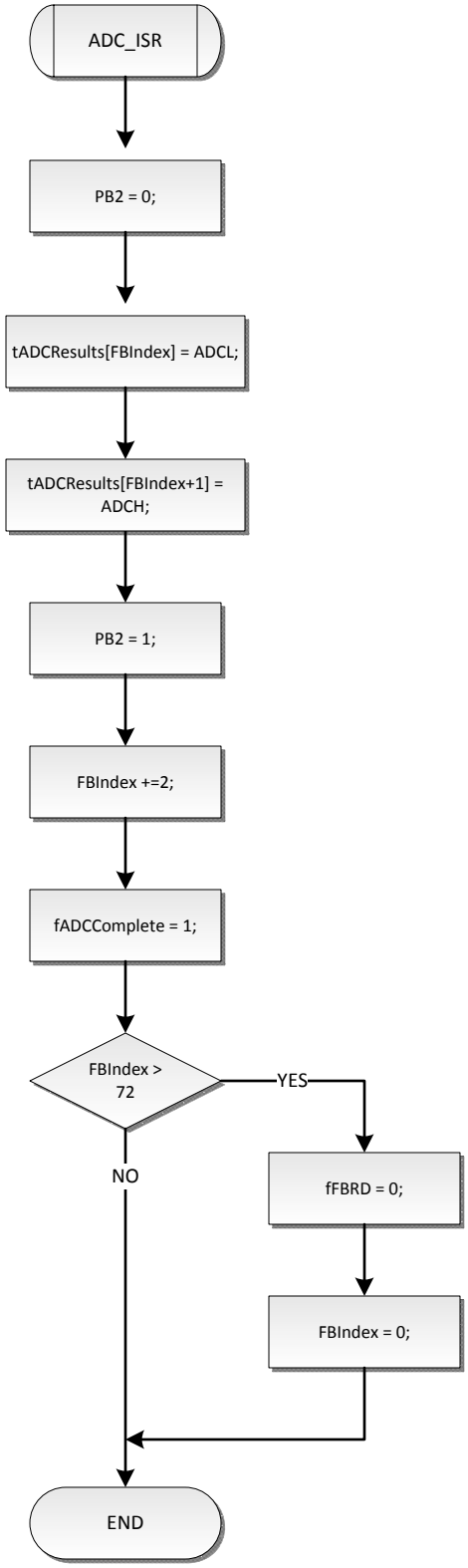
TIMER0 ISR



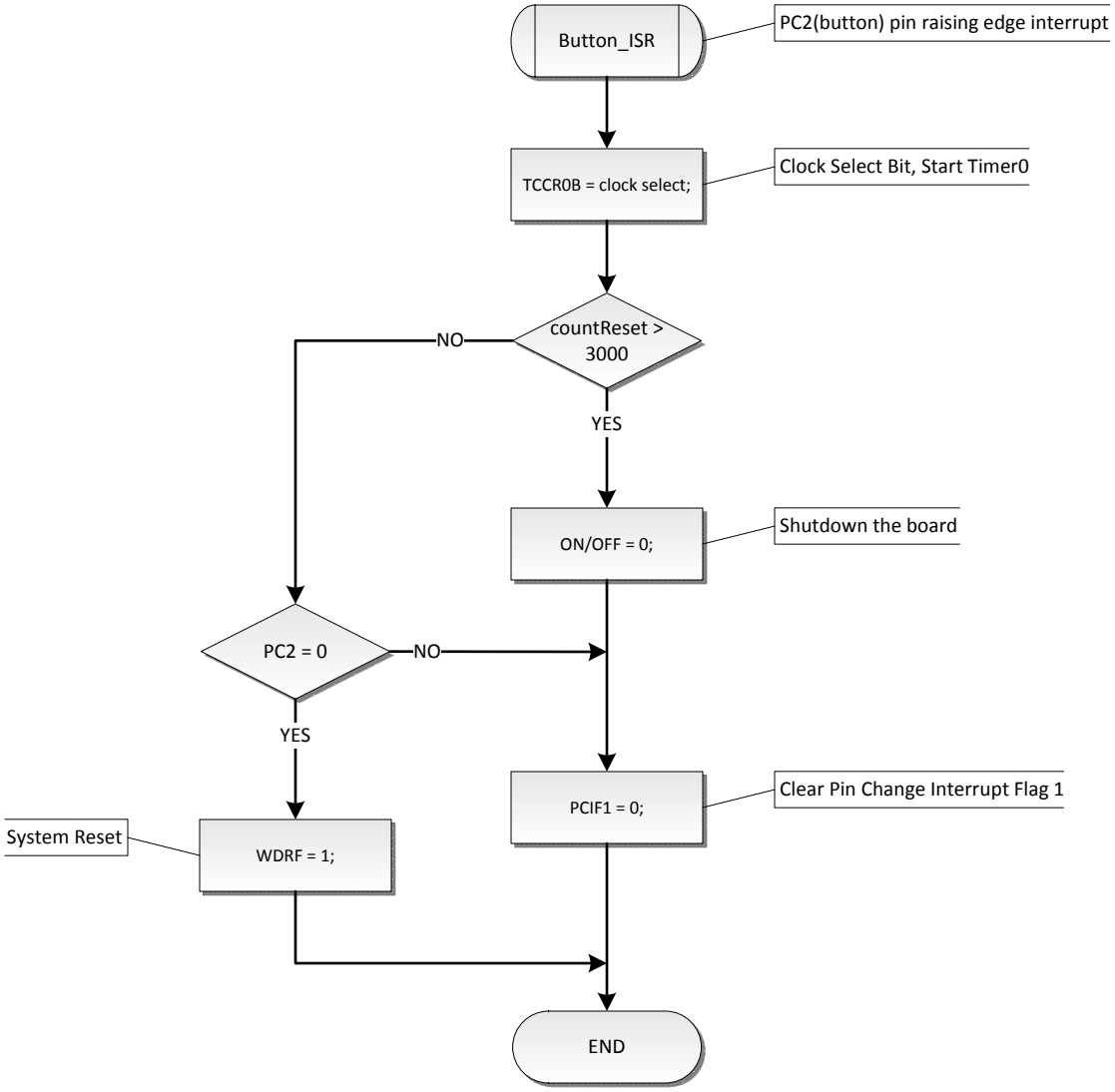
TIMER1 ISR



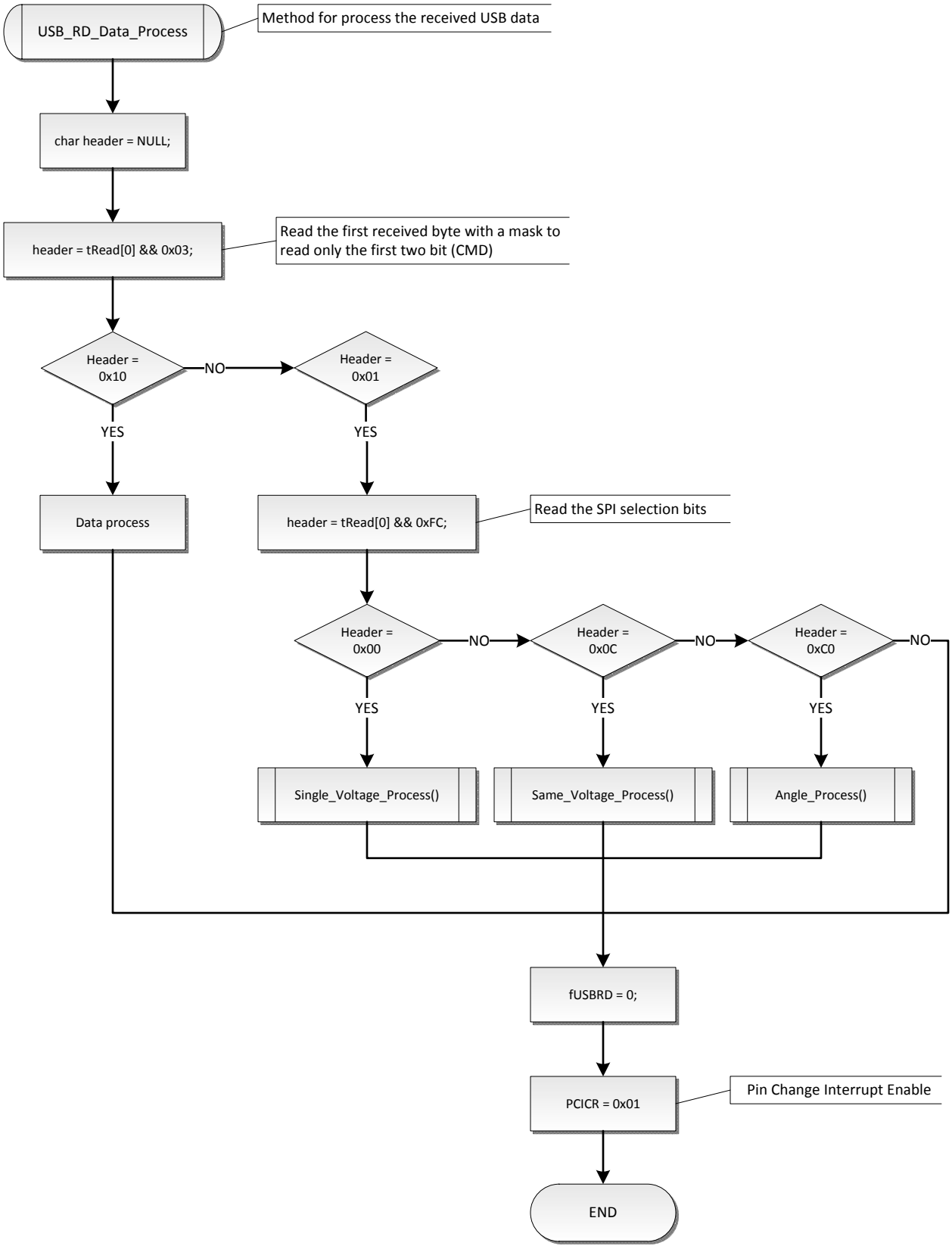
ADC ISR


ADC_ISR
PB2 = 0;
tADCResults[FBIndex] = ADCL;
tADCResults[FBIndex+1] = ADCH;
PB2 = 1;
FBIndex +=2;
fADCComplete = 1;
FBIndex > 72
YES
NO
fFBRD = 0;
FBIndex = 0;
END

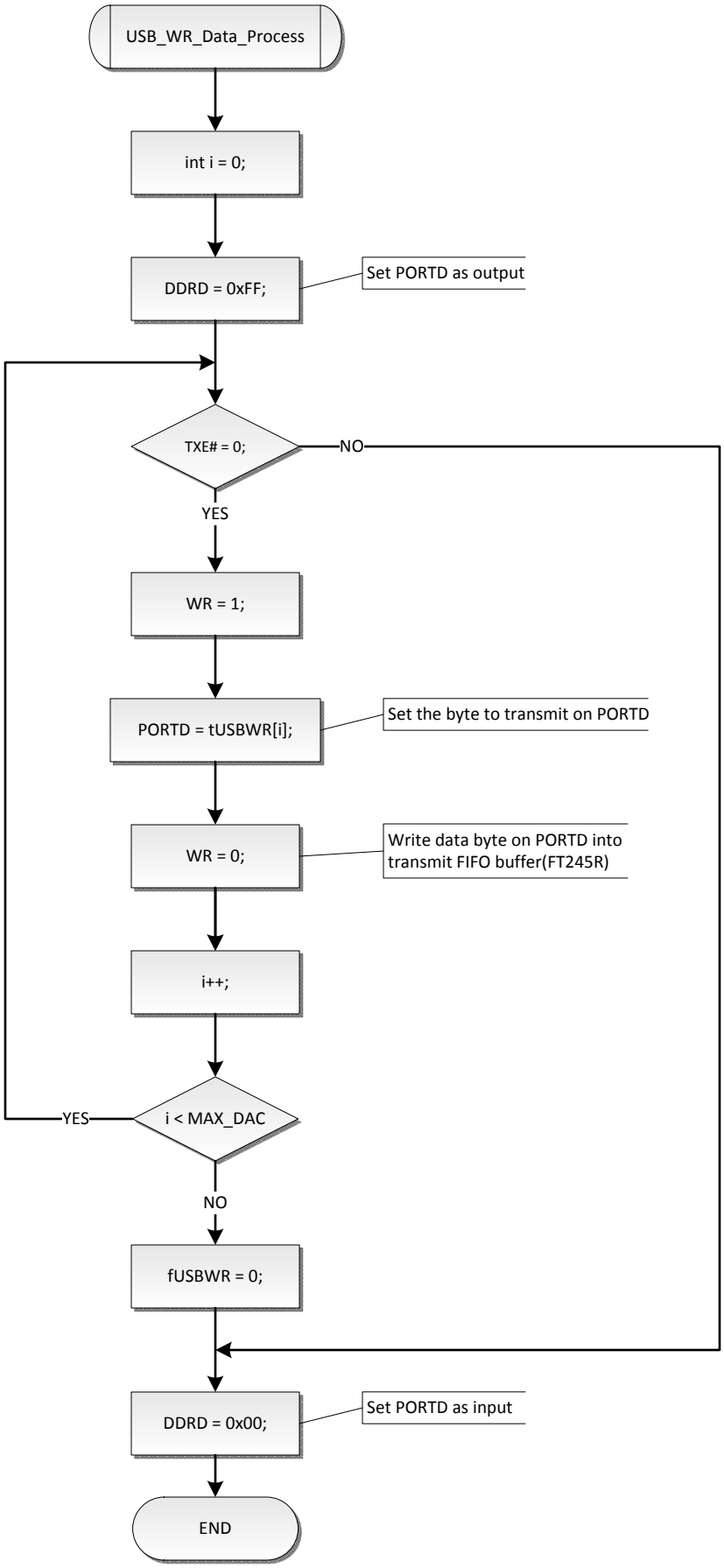
Button ISR


Button_ISR
PC2(button) pin raising edge interrupt
TCCR0B = clock select;
Clock Select Bit, Start Timer0
countReset > 3000
NO
YES
ON/OFF = 0;
Shutdown the board
PC2 = 0
NO
YES
PCIF1 = 0;
Clear Pin Change Interrupt Flag 1
System Reset
WDRF = 1;
END

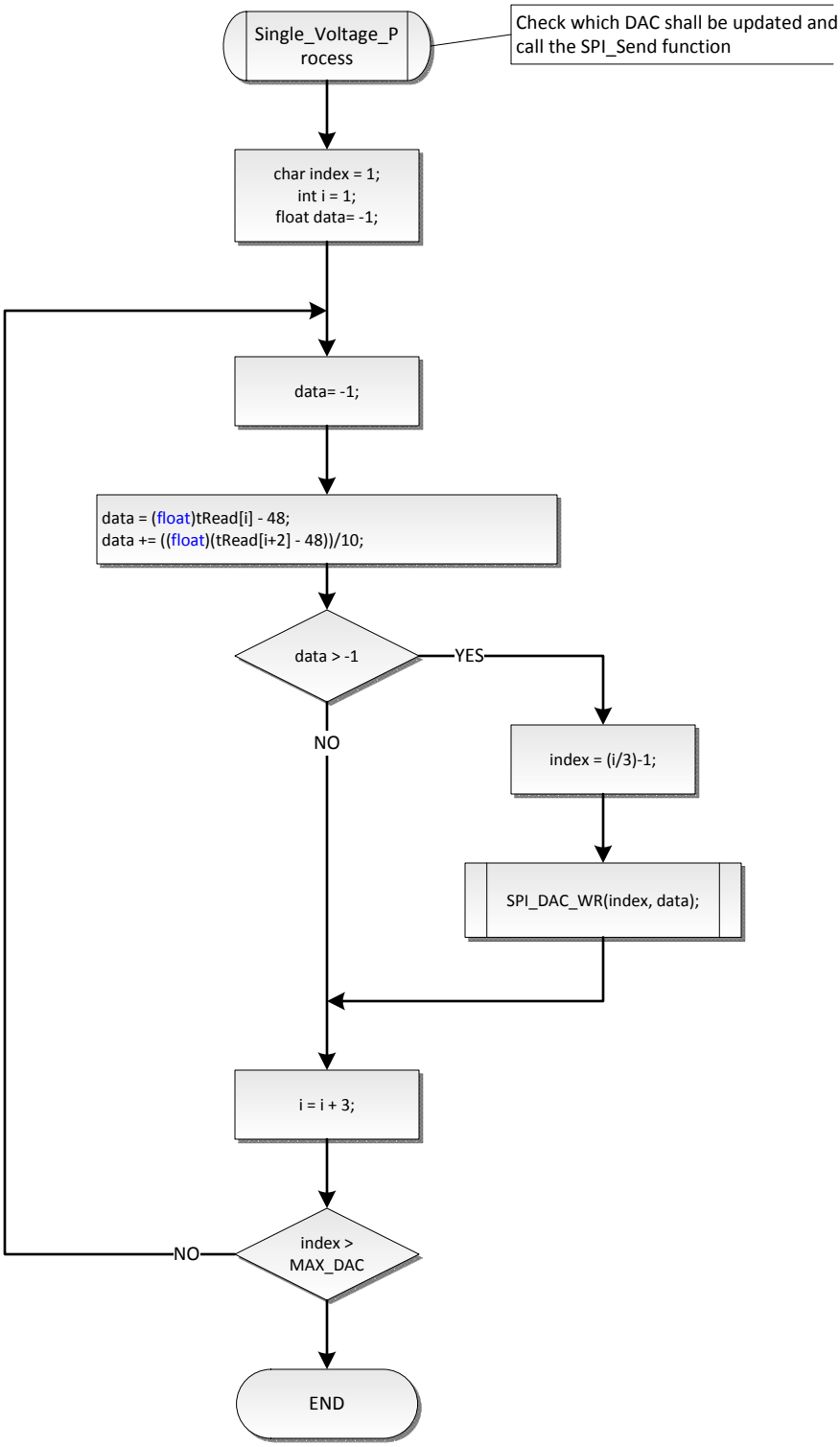
USB RD Data Process



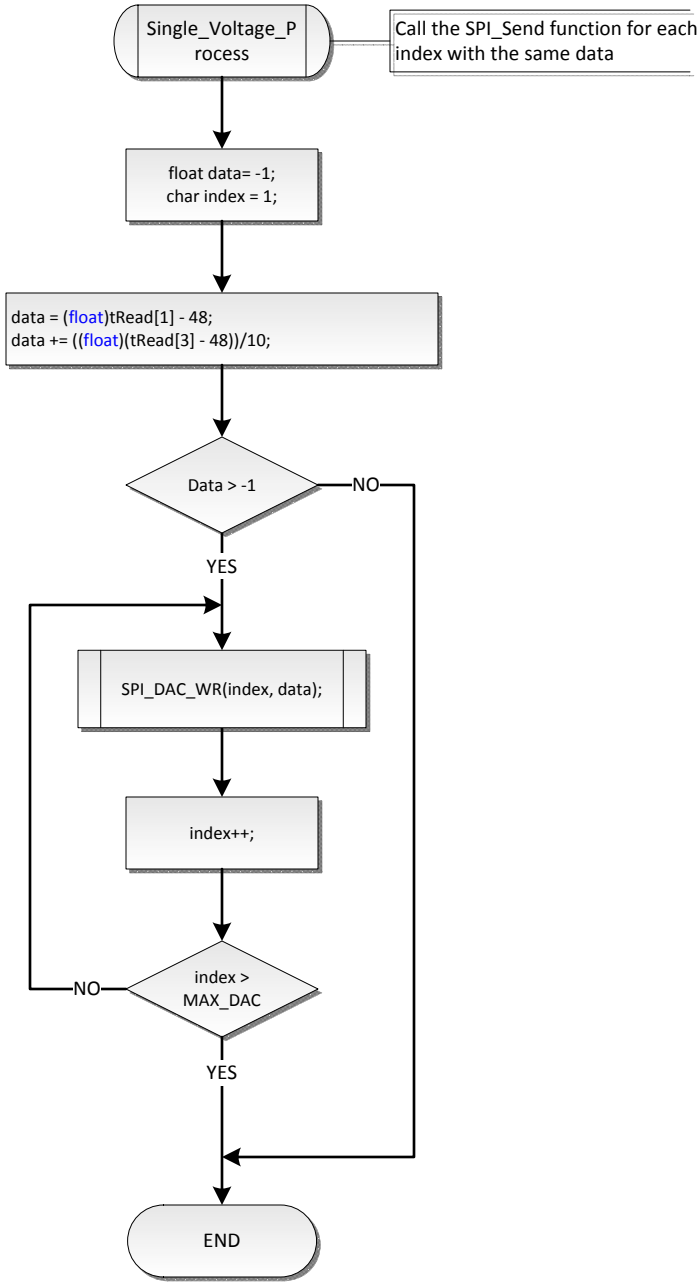
USB WR Data Process



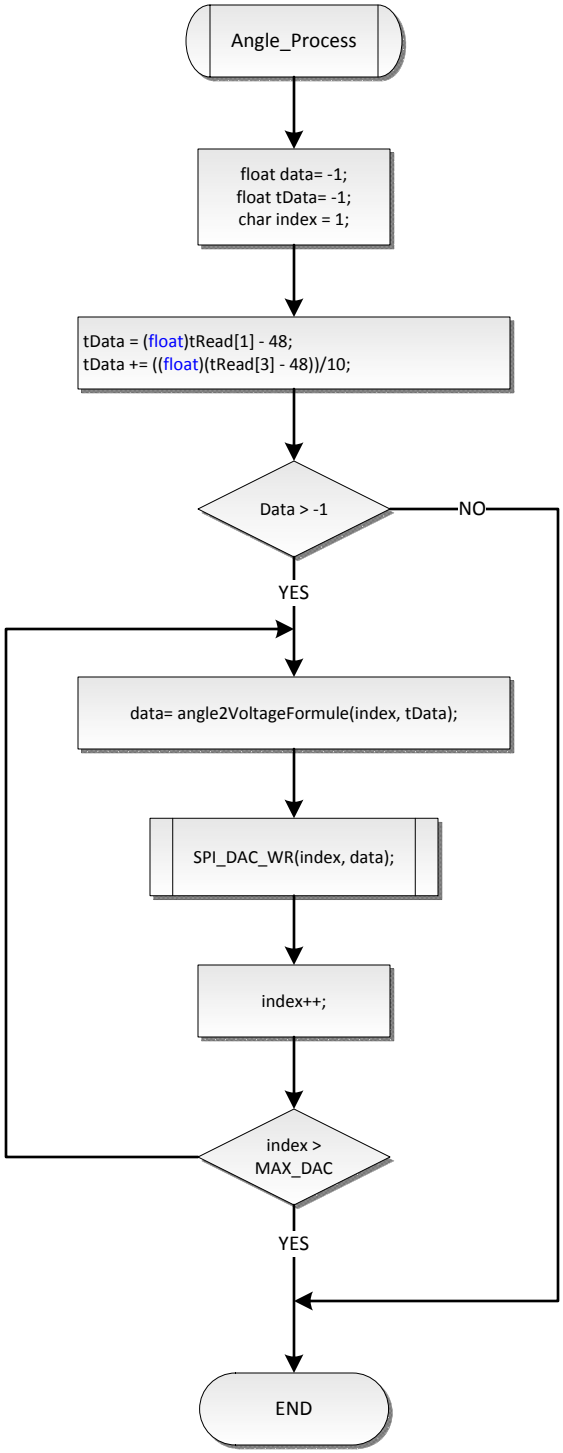
Single Voltage Process



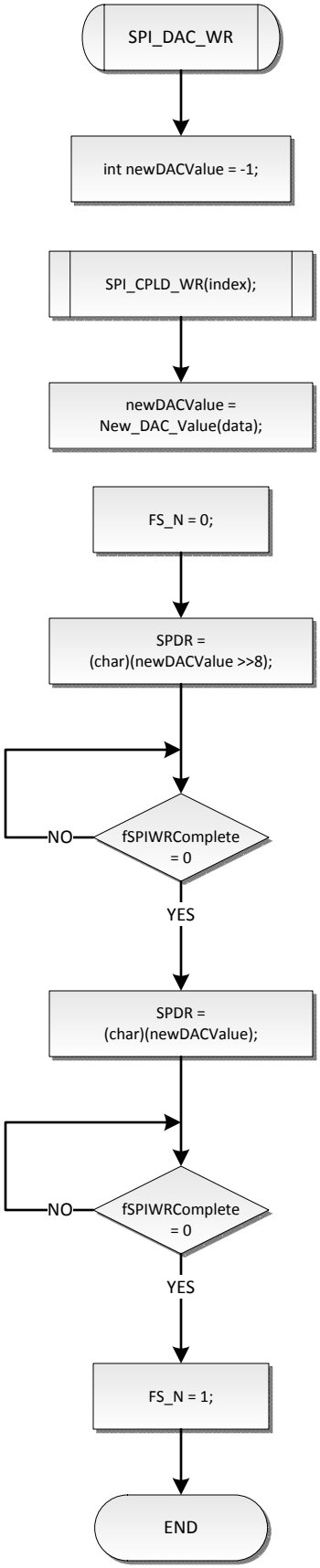
Same Voltage Process



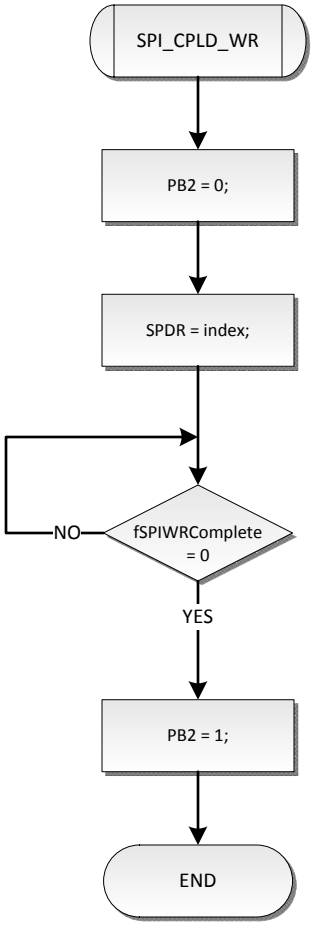
Same Voltage Process



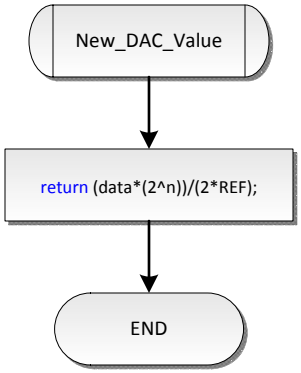
SPI DAC WR


SPI_DAC_WR
int newDACValue = -1;
SPI_CPLD_WR(index);
newDACValue =
New_DAC_Value(data);
FS_N = 0;
SPDR =
(char)(newDACValue >>8);
NO
fSPIWRComplete
= 0
YES
SPDR =
(char)(newDACValue);
NO
fSPIWRComplete
= 0
YES
FS_N = 1;
END

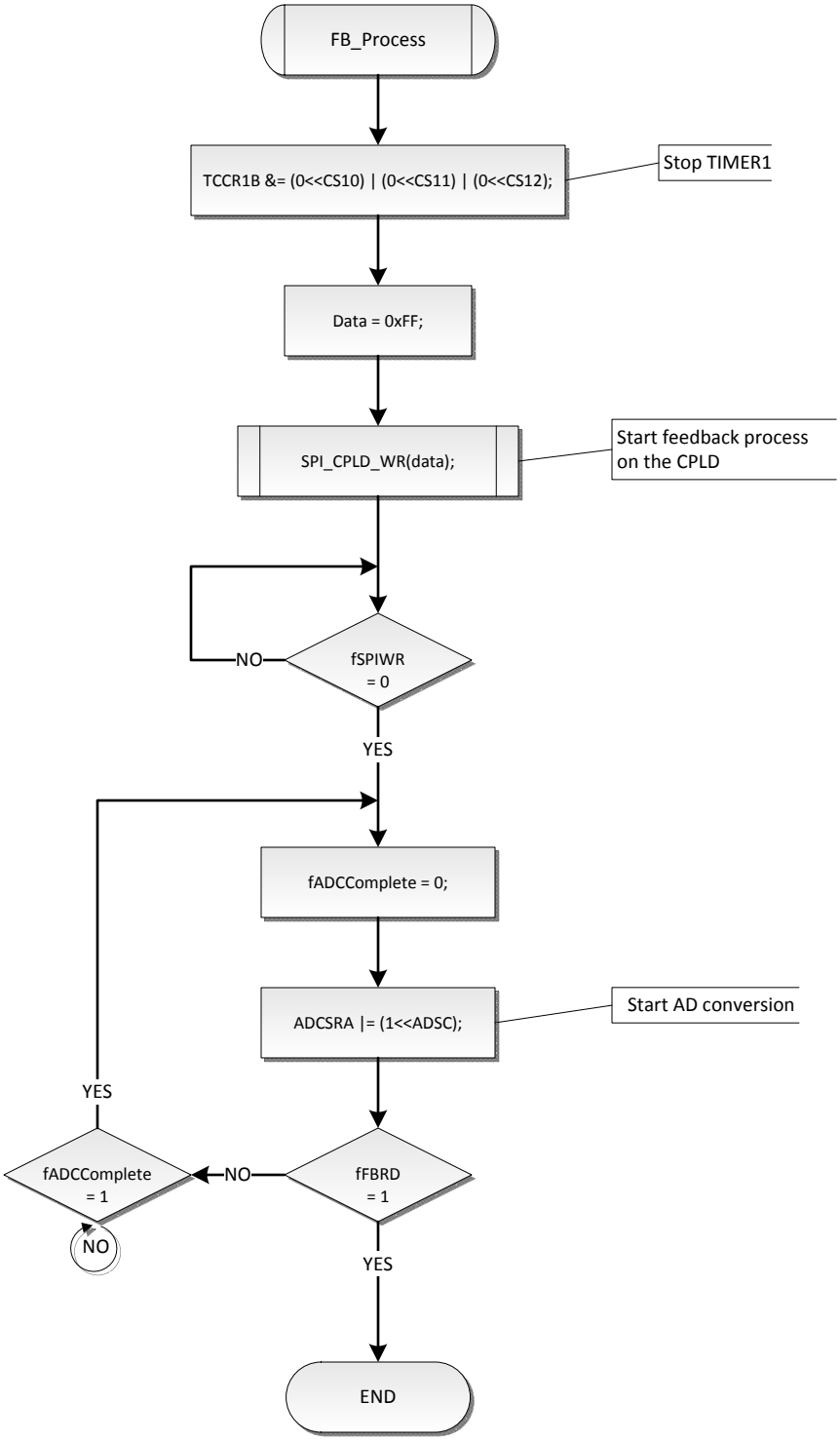
SPI CPLD WR


SPI_CPLD_WR
PB2 = 0;
SPDR = index;
NO
fSPIWRComplete = 0
YES
// Possibility to read
PB2 = 1;
END

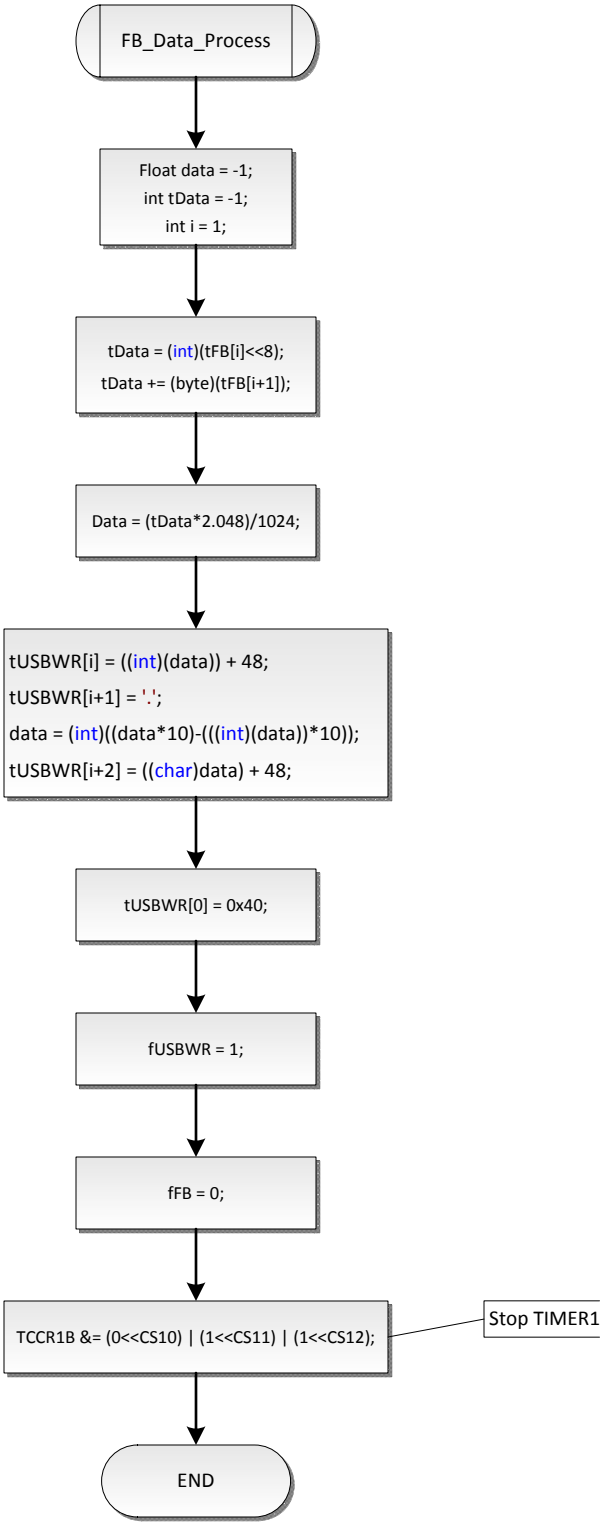
New DAC Value



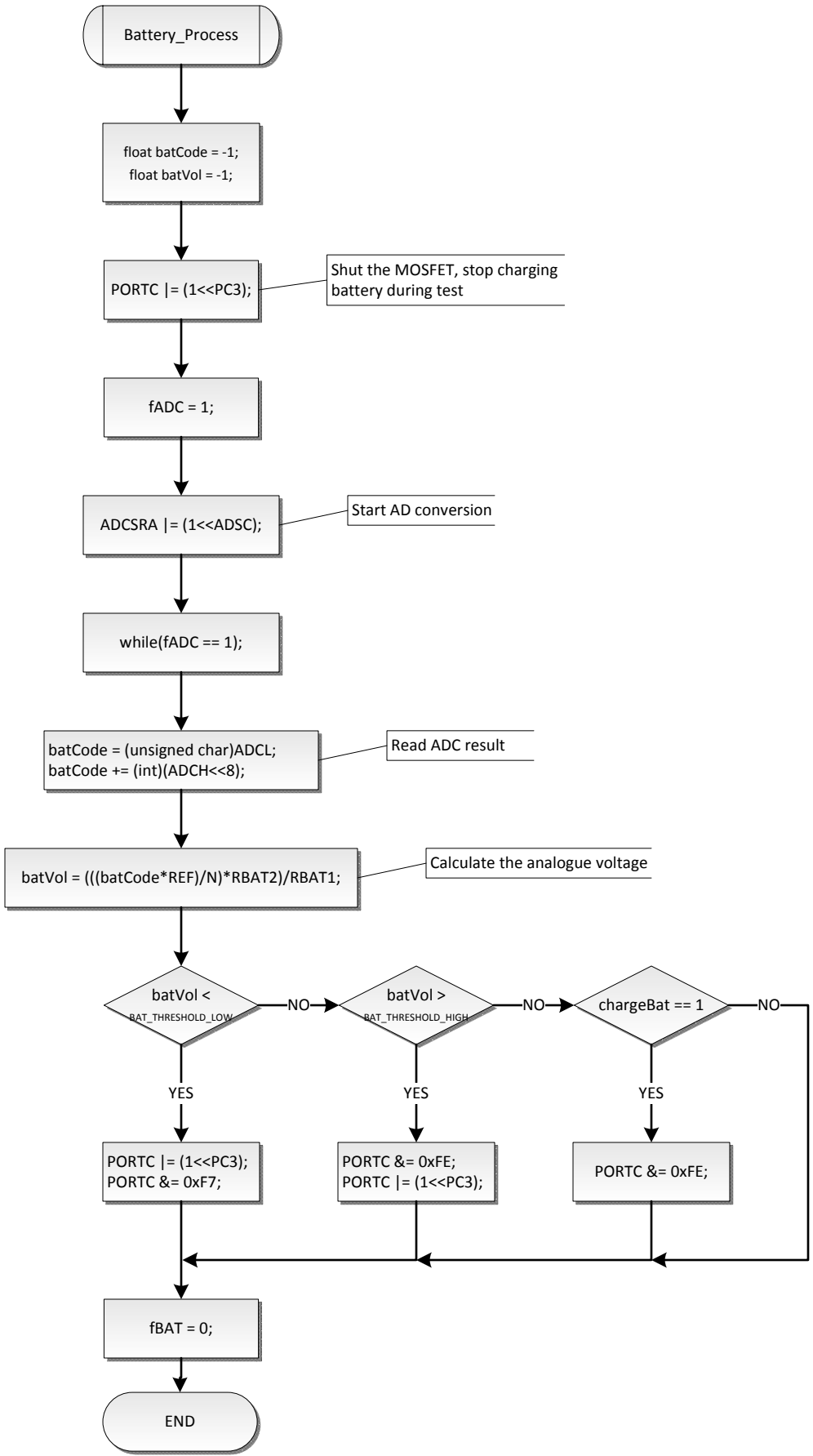
FB Process


FB_Process
TCCR1B &= (0<<CS10) | (0<<CS11) | (0<<CS12);
Stop TIMER1
Data = 0xFF;
SPI_CPLD_WR(data);
Start feedback process on the CPLD
fSPIWR = 0
NO
YES
fADCComplete = 0;
ADCSRA |= (1<<ADSC);
Start AD conversion
fFBRD = 1
NO
fADCComplete = 1
NO
YES
YES
END

FB Data Process



Battery Process



```
/*****************************************************************************/
/* FILENAME :   USBSPITranslator.c                                           */
/* AUTHOR   :   Salamin Yannick     <yannick.salamin@gmail.com>              */
/*---------------------------------------------------------------------------*/
/* FUNCTION :   Realizing the bidirectional translation between USB FIFO     */
/*              interface and SPI protocol. DACs feedback processing and     */
/*              battery management                                           */
/*---------------------------------------------------------------------------*/
/* REVISION :   1.0 (version for ATmega88)                                   */
/*****************************************************************************/


#include <avr/io.h>
#include <avr/signal.h>
#include <avr/interrupt.h>

/*****************************************************************************/
/*  Global definitions & declarations                                        */
/*****************************************************************************/

/* Constants */
#define N 1024
#define REF 2.5
#define MAX_DAC 37
#define RBAT1 200
#define RBAT2 300
#define BAT_THRESHOLD_LOW 2.2
#define BAT_THRESHOLD_HIGH 3.6

/* Arrays */
char tUSBRD[37*3];
char tUSBWR[37*3];
char tFBData[37*2];
float tDACWR[37];

/* Variables */
int countReset = 0;
int FBIndex    = 0;
int countBAT   = 0;
int countFB    = 0;
int chargeBat  = 0;

/* Flags */
int fUSBRD = 0;
int fUSBWR = 0;
int fSPIWR = 0;
int fFB    = 0;
int fFBRD  = 0;
int fADC   = 0;
int fBAT   = 0;

/* Functions */
void USB_RD_Data_Process();
void FB_Process();
void FB_Data_Process();
void USB_WR_Data_Process();
void Single_Voltage_Process();
void Same_Voltage_Process();
void Angle_Process();
```

```
void SPI_DAC_WR(char index,int data);
void SPI_CPLD_WR(char index);
int New_DAC_Value(float data);
void Battery_Process();

/*****************************************************************************/
/* FUNCTION     : init()                                                     */
/* INPUT        : -                                                          */
/* OUTPUT       : -                                                          */
/* COMMENTS     : Peripherals initialization                                 */
/*****************************************************************************/
void init(void)
{
    /*-------------------------------------------------------------------------*/
    /*      Status register initialisation                                     */
    /*-------------------------------------------------------------------------*/
    SREG   = 0x00;                          // Reset status register

    /*-------------------------------------------------------------------------*/
    /*      Power management initialisation :   Power down                     */
    /*-------------------------------------------------------------------------*/
    SMCR   = 0x04;                          // Select "Power down" mode without
                                            // enabling to enter in sleep mode
    /*-------------------------------------------------------------------------*/
    /*      I/O initialisation                                                 */
    /*-------------------------------------------------------------------------*/

    /* PORTB, SPI */
    DDRB   = 0x2F;                          // Set PB0(RD),PB1(WR),PB2(CS),
                                            // PB3(MOSI) and PB5(SCLK) as output
                                            // Set PB4(MISO_P),PB6(RXF) and PB7(TXE) as
                                            input

    //DDRB = (1<<PB2);

    PORTB  = (1<<PB0) | (1<<PB2);           // Set initial pins value: RD and CS high
    //PORTB = 0x05;



    /* PORTC*/
    DDRC   = 0xFB;                          // Set PC0(LEDB),PC1(LEDP),PC3(charge),
                                            // PC4(FS_N) and PC5(ON/OFF) as output
                                            // Set PC2(button) as input

    // Set initial pins value: LEDP,FS_N,ON/OFF high
    PORTC  = (1<<PC1) | (1<<PC3) | (1<<PC4)  | (1<<PC5);

    /* PORTD, USB FIFO */
    DDRD   = 0x00;                          // Set PORTD as input

    /*-------------------------------------------------------------------------*/
    /*      Timer0 initialisation:  1ms                                        */
    /*-------------------------------------------------------------------------*/
    TCCR0A = 0x02;                          // Set CTC operation mode
    TCCR0B = 0xC0;                          // Prescaler: 8, TIMER0 disable
    OCR0A  = 0x7D;                          // A output compare value: 250
    TIMSK0 = 0x02;
    TIFR0  = 0x02;                          // Enable A output match interrupt
```

```
    /*-------------------------------------------------------------------------*/
    /*      Timer1 initialisation:  1s                                         */
    /*-------------------------------------------------------------------------*/
    TCCR1A = 0x00;                          // Set CTC operation mode
    TCCR1B = 0x0B;                          // Set prescaler 64
    TCCR1C = 0xC0;
    OCR1AH = 0x3D;                          // A output compare value:15625
    OCR1AL = 0x09;
    TIMSK1 = 0x02;
    TIFR1  = 0x02;                          // Enable A output match interrupt

    /*-------------------------------------------------------------------------*/
    /*      Pin Change Interrupt init:  PCINT6(RXF#), PCINT10(Button)          */
    /*-------------------------------------------------------------------------*/
    PCICR  = 0x03;                          // Enable PCIE0 and PCIE1 interrupt
    PCMSK0 = 0x40;                          // Enable PCINT6
    interrupt
    PCMSK1 = 0x04;                          // Enable PCINT10 interrupt

    /*-------------------------------------------------------------------------*/
    /*      SPI initialisation: Master                                         */
    /*-------------------------------------------------------------------------*/
    SPCR   = 0xD8;                          // Set SPI enable and as master
    SPSR   |= (1<<SPI2X);                   // Enable double SPI speed, clk/2

    /*-------------------------------------------------------------------------*/
    /*      ADC initialisation:                                                */
    /*-------------------------------------------------------------------------*/
    ADMUX  = 0x07;                          // Set AVref(2.5V) and select ADC6(feedback)
    ADCSRA = 0x8C;                          // SetADC prescaler: 16 and enable interrupt
}

/*****************************************************************************/
/* FUNCTION     : main()                                                     */
/* INPUT        : -                                                          */
/* OUTPUT       : -                                                          */
/* COMMENTS     : Main function                                              */
/*****************************************************************************/
int main(void)
{
    init();                                 // Initialisation function call
    sei();                                  // Enable global interrupt

    while(1)
    {
        if(fUSBRD == 1)                     // Check if usb received data wait to be
        process
        {
            USB_RD_Data_Process();          // Call usb received data process function
        }

        if(fFB == 1)                        // Check if feedback should be updated
        {
            FB_Process();                   // Call feedback update process function
            FB_Data_Process();              // Call feedback data process function
            fFB = 0;
        }
```

```
        if(fUSBWR == 1)                         // Check if usb data need to be send
        {
            USB_WR_Data_Process();              // Call usb write data function
        }

        if(fBAT == 1)                           // Check if battery need to be tested
        {
            Battery_Process();                  // Call battery test funtion
        }
    }

    return 0;
}

/*****************************************************************************/
/* FUNCTION     : USB_RD_Data_Process()                                      */
/* INPUT        : -                                                          */
/* OUTPUT       : -                                                          */
/* COMMENTS     : Process the received usb data                              */
/*****************************************************************************/
void USB_RD_Data_Process()
{
    char header;
    int i = 1;

    header = tUSBRD[0];

    if((header&0x03) == 0x02)
    {
        switch(header&0x0FC)
        {
            case 0x00:
                Single_Voltage_Process();       // Call single voltage update function
                break;

            case 0x0C:
                Same_Voltage_Process();         // Call all the same voltage update function
                break;

            case 0xC0:
                Angle_Process();                // Call angle process funtion
                break;

            default:
                break;
        }
    }
    else if(header == 0x01)
    {

    }
    else
    {
    }

    for(i=0;i<MAX_DAC*3;i++)
    {
        tUSBRD[i] = 0x00;                       // Reset usb read buffer
    }
```

```
    fUSBRD = 0;                                 // Clear USB read flag
    PCICR = 0x03;                               // Enable pin change interrupt on PB6
}

/*****************************************************************************/
/* FUNCTION     : USB_WR_Data_Process()                                      */
/* INPUT        : -                                                          */
/* OUTPUT       : -                                                          */
/* COMMENTS     : Write data into the USB controler                          */
/*****************************************************************************/
void USB_WR_Data_Process()
{
    int i = 0;

    DDRD = 0xFF;                                // Set PORTD as output

    for(i=0;i<37;i++)
    {
        if((PINB&0x80) == 0x00)                 // Check that usb controler is able to
        receive data
        {

            PORTB |= (1<<PB1);                  // Pull up WR
            PORTD = tUSBWR[i];                  // Prepare PORTD with data to write
            PORTB = (0<<PB1);                   // Pull down WR, write data in usb
            controler
            fUSBWR = 0;                         // Reset USB write flag
        }
        else
        {
            fUSBWR = 1;
        }
    }

    TCCR1B = 0x0B;                              // Start Timer 1
    DDRD = 0x00;                                // Set PORTD as input
}

/*****************************************************************************/
/* FUNCTION     : Single_Voltage_Process()                                   */
/* INPUT        : -                                                          */
/* OUTPUT       : -                                                          */
/* COMMENTS     : Update single DAC voltage                                  */
/*****************************************************************************/
void Single_Voltage_Process()
{
    char index = 1;
    int tDigitalDAC[37];

    do
    {
        if(tDACWR[index-1]>-1)                  // Check if data to update
        {
            tDigitalDAC[index-1] = New_DAC_Value(tDACWR[index-1]);// Calculate new digital
            value to update
        }
        else
        {
```

```
            tDigitalDAC[index-1] = -1;
        }

        index++;                                // Update index from increment value to
        determine which DAC to update

    }while(index<(MAX_DAC+1));                  // Check all 37 DAC

    index = 1;

    do
    {
        if(tDigitalDAC[index-1]>-1)             // Check if data to update
        {
            SPI_DAC_WR(index,tDigitalDAC[index-1]); // Call DAC write function with the
            index and value to update
        }

        index++;                                // Update index from increment value to
        determine which DAC to update

    }while(index<(MAX_DAC+1));                  // Check all 37 DAC

    SPI_CPLD_WR(0x00);                          // Reset the chips selection
}

/*****************************************************************************/
/* FUNCTION     : Same_Voltage_Process()                                     */
/* INPUT        : -                                                          */
/* OUTPUT       : -                                                          */
/* COMMENTS     : Update DAC with the same voltage                           */
/*****************************************************************************/
void Same_Voltage_Process()
{
    char index = 50;                            // Index value to update all the DACs

    SPI_DAC_WR(index,New_DAC_Value(tDACWR[0])); // Call DAC write function with the index
    and the digital value to update

    SPI_CPLD_WR(0x00);                          // Reset the chips selection
}

/*****************************************************************************/
/* FUNCTION     : Angle_Process()                                            */
/* INPUT        : -                                                          */
/* OUTPUT       : -                                                          */
/* COMMENTS     : Update DAC with voltage corresponding to the angle         */
/*****************************************************************************/
void Angle_Process()
{
    char index = 0;
    int tDigitalDAC[37];

    do
    {
        tDigitalDAC[index] = New_DAC_Value(tDACWR[index]);// Calculate new digital value to
        update

        index++;                                // Update index from increment value to
```

```
        determine which DAC to update

    }while(index<MAX_DAC);                      // Check all 37 DAC

    index = 2;

    do
    {
        SPI_DAC_WR(index,tDigitalDAC[index-2]);
        index++;
    }while(index<MAX_DAC+1);                    // Update all 37 DAC

    SPI_CPLD_WR(0x00);                          // Reset the chips selection
}

/*****************************************************************************/
/* FUNCTION     : SPI_DAC_WR()                                               */
/* INPUT        : char, float                                                */
/* OUTPUT       : -                                                          */
/* COMMENTS     : Write digital voltage into SPI channel                     */
/*****************************************************************************/
void SPI_DAC_WR(char index,int data)
{
    PORTB |= (1<<PB2);

    SPI_CPLD_WR(index);                         // Call cpld write function to select the DAC

    PORTC  = 0xEA;                              // Pull down FS_N, indicate new value

    SPCR |= (1<<SPIE);                          // Enable SPI interrupt
    fSPIWR = 1;                                 // Set SPI writing flag
    SPDR = (char)(data>>8);                     // Write new DAC value

    while(fSPIWR == 0);                         // Wait for SPI transfert complete

    SPCR |= (1<<SPIE);                          // Enable SPI interrupt
    fSPIWR = 1;                                 // Set SPI writing flag
    SPDR = (char)(data);                        // Write new DAC value

    while(fSPIWR == 0);                         // Wait for SPI transfert
    complete

    PORTC  |= (1<<PC4);                         // Pull up FS_N
}

/*****************************************************************************/
/* FUNCTION     : SPI_CPLD_WR(char index)                                    */
/* INPUT        : char                                                       */
/* OUTPUT       : -                                                          */
/* COMMENTS     : Send index, DAC to select, to the CPLD through SPI channel */
/*****************************************************************************/
void SPI_CPLD_WR(char index)
{
    PORTB  = (0<<PB2);                          // Pull down CS, select CPLD to write SPI

    SPCR |= (1<<SPIE);                          // Enable SPI interrupt
    fSPIWR = 1;                                 // Set SPI writing flag
    SPDR = index;                               // Write index, DAC to select, to the CPLD
```

```
    while(fSPIWR == 0);                         // Wait for SPI transfert complete

    PORTB |= (1<<PB2);                          // Pull up CS, CPLD transfert finished
}

/*****************************************************************************/
/* FUNCTION     : FB_Process()                                               */
/* INPUT        : -                                                          */
/* OUTPUT       : -                                                          */
/* COMMENTS     : Update the feedback values                                 */
/*****************************************************************************/
void FB_Process()
{
    char index;
    FBIndex = 0;
    fFBRD = 1;

    TCCR1B &= (0<<CS10) | (0<<CS11) | (0<<CS12);// Stop Timer1
    ADMUX  = 0x06;                              // Select ADC6(feedback)

    index = 0x64;                               // Set feedback update index
    SPI_CPLD_WR(index);                         // Inform CPLD of feedback process

    do
    {
        fADC = 1;                               // Clear ADC complete flag
        ADCSRA |= (1<<ADSC);                    // Start AD conversion
        while(fADC == 1);                       // Wait for AD conversion complete

        tFBData[FBIndex] = ADCL;                // Store AD conversion results
        tFBData[FBIndex+1] = ADCH;

        PORTB  = (0<<PB2);                      // Pull down CS, CPLD increment mux
        address
        PORTB  |= (1<<PB2);                     // Pull up CS

        FBIndex += 2;                           // Increment index

        if(FBIndex > MAX_DAC*2)                 // Check if all DAC were read
        {
            fFBRD = 0;                          // Clear feedback flag
            FBIndex = 0;                        // Reset feedback index
        }

    }while(fFBRD == 1);                         // Read all 37 DAC


    ADMUX  = 0x07;                              // Select ADC7(Battery)
}

/*****************************************************************************/
/* FUNCTION     : FB_Data_Process()                                          */
/* INPUT        : -                                                          */
/* OUTPUT       : -                                                          */
/* COMMENTS     : process the FB data in order to send them to the computer  */
/*****************************************************************************/
void FB_Data_Process()
{
    float data = -1;
```

```
    long tData = -1;
    int i = 1;
    int index = 1;

    do
    {
        tData = 0;
        data  = 0;

        tData = (tFBData[index]<<8);            // Read feedback data
        tData += (tFBData[index-1]);

        data = (tData*REF)/(N);                 // Calcule the analogue equivalent value
        //data = data*5;
        //data = data - 3.5;


        tUSBWR[i]   = ((int)(data))+48;             // Write the first digit in the write
        buffer
        tUSBWR[i+1] = '.';                          // Write the dote in the write buffer

        data = (int)((data*10)-(((int)(data))*10)); // Format second digit

        tUSBWR[i+2] = ((char)data)+48;              // Write second digit in the write buffer

        i+=3;
        index+=2;

    }while(i<MAX_DAC*3+1);




    fUSBWR = 1;                                 // Set usb write flag
    fFB = 0;                                    // Clear feedback flag


}

/*****************************************************************************/
/* FUNCTION     : New_DAC_Value(float data)                                  */
/* INPUT        : -                                                          */
/* OUTPUT       : int                                                        */
/* COMMENTS     : Return digital voltage value in the                        */
/*****************************************************************************/
int New_DAC_Value(float data)
{
    int temp = (data*(N))/(2*REF);              // Calculate new digital value for DAC

    return temp<<2;
}

/*****************************************************************************/
/* FUNCTION     : Battery_Process()                                          */
/* INPUT        : -                                                          */
/* OUTPUT       : -                                                          */
/* COMMENTS     : Check if the battery need to be charge                     */
/*****************************************************************************/
void Battery_Process()
```

```
{
    int batCode = 0;
    float batVol = 0;

    PORTC |= (1<<PC3);                          // Shut the MOSFET, stop charging battery
    during test

    ADMUX  = 0x07;                              // Select ADC7(Battery)

    fADC = 1;                                   // Clear ADC complete flag
    ADCSRA |= (1<<ADSC);                        // Start AD conversion

    while(fADC == 1);                           // Wait for AD conversion complete

    batCode = (unsigned char)ADCL;              // Read AD conversion results
    batCode += (int)(ADCH<<8);

    batVol = (((batCode*REF)/N)*RBAT2)/RBAT1;   // Calculate the real analogue voltage

    if(batVol < BAT_THRESHOLD_LOW)              // Check if battery is full
    {
        PORTC |= (1<<PC0);                      // Turn on the Battery LED
        PORTC &= 0xF7;                          // Start charging battery
        chargeBat = 1;
    }
    else if(batVol > BAT_THRESHOLD_HIGH)        // Check if battery need to be charged
    {
        PORTC &= 0xFE;                          // Turn off the Battery LED
        PORTC |= (1<<PC3);                      // Shut the MOSFET, stop charging battery
        chargeBat = 0;
    }
    else
    {
        if(chargeBat == 1)
        {
            PORTC &= 0xF7;                      // Charge battery
        }
    }

    fBAT = 0;                                   // Clear battery check flag
}
```

```
/*****************************************************************************/
/* FILENAME :   interrupt.c                                                  */
/* AUTHOR   :   Salamin Yannick     <yannick.salamin@gmail.com>              */
/*---------------------------------------------------------------------------*/
/* FUNCTION :   Execute all interrupt handling routine.                      */
/*---------------------------------------------------------------------------*/
/* REVISION :   1.0 (version for ATmega88)                                   */
/*****************************************************************************/

#include <avr/io.h>
#include <avr/signal.h>
#include <avr/interrupt.h>
#include <avr/sleep.h>

#define MAX_DAC 37
#define SHUTDOWN_TIME 3000
#define RESET_TIME 1000
#define BAT_TIME 100

extern int countReset;
extern int countFB;
extern int countBAT;
extern int fUSBRD;
extern int fSPIWR;
extern int fFB;
extern int fFBRD;
extern int fADC;
extern int fBAT;
extern char tUSBRD[37*3];
extern float tDACWR[37];

/*****************************************************************************/
/* FUNCTION     : TIMER0_COMPA_vect                                          */
/* INPUT        : -                                                          */
/* OUTPUT       : -                                                          */
/* COMMENTS     : ISR for Timer 0                                            */
/*****************************************************************************/
SIGNAL(TIMER0_COMPA_vect)
{
    countReset++;                               // Increment board reset counter
}

/*****************************************************************************/
/* FUNCTION     : TIMER1_COMPA_vect                                          */
/* INPUT        : -                                                          */
/* OUTPUT       : -                                                          */
/* COMMENTS     : ISR for Timer 1                                            */
/*****************************************************************************/
SIGNAL(TIMER1_COMPA_vect)
{
    if(countBAT > BAT_TIME)
    {
        countBAT = 0;
        fBAT = 1;
    }
    else
    {
        countBAT++;
    }
```

```
    if(countFB > 5)
    {
        fFB = 1;                                // Set feedback update flag
        countFB = 0;
    }
    else
    {
        countFB++;
    }
}

/*****************************************************************************/
/* FUNCTION     : PCINT0_vect                                                */
/* INPUT        : -                                                          */
/* OUTPUT       : -                                                          */
/* COMMENTS     : ISR for PB6(RXF#) level change                             */
/*****************************************************************************/
SIGNAL(PCINT0_vect)
{
    int i = 0;
    int index = 0;
    float data = -1;

    PCICR = 0x02;                               // Disable pin change interrupt for PB6

    do
    {
        if((PINB&0x40) == 0x00)                 // Check if PB6(RXF#) is low
        {
            PORTB  = (0<<PB0);                  // Pull down PB0(RD) in order to fetch next
            (if available) data byte from the receive buffer
            tUSBRD[i] = PIND;                   // Read PORTB
            PORTB  |= (1<<PB0);                 // Pull up PB0(RD)
            i++;                                // Increment buffer index
        }
        else
        {
            break;                              // Break out the loop if PB6(RXF#) is high
        }

    }while(i<(MAX_DAC*3)+1);                    // Read all 37 new DAC value

    i = 1;                                      // Reset index for next buffer

    do
    {
        data = -1;

        data = (float)tUSBRD[i]-48;             // Read digit before the virgule
        data += ((float)(tUSBRD[i+2]-48))/10;   // Read digit after the virgule


        if(data != 9.9)
        {
            data = data + 3.6;                  // Add DACs voltage offset
            data = data/5;                      // Divide the DACs amplification

            tDACWR[index] = data;               // Store the data
```

```
        }
        else
        {
            tDACWR[index] = -1;                 // No charging value
        }

        i += 3;                                 // Increment index to read next received value
        index++;                                // Increment index for next value

    }while(index<MAX_DAC);


    if(tUSBRD[0] != 0xFF)                       // Check if read buffer is empty
    {
        fUSBRD = 1;                             // If read buffer is not empty, set USBRD flag
    }
}

/*****************************************************************************/
/* FUNCTION     : PCINT1_vect                                                */
/* INPUT        : -                                                          */
/* OUTPUT       : -                                                          */
/* COMMENTS     : ISR for PC2(Button) level change                           */
/*****************************************************************************/
SIGNAL(PCINT1_vect)
{
    sei();                                      // Enable global interrupt

    if((PINC&0x04) == 0x04)
    {
        TCCR0B = 0xC2;                          // Start TIMER0
    }

    if(countReset > SHUTDOWN_TIME)
    {
        PORTC = (0<<PC5);                       // Shut down the board
    }
    else
    {
        if((PINC&0x04) == 0x00)
        {
            TCCR0B = 0xC0;                      // Stop TIMER0
            TCNT0 = 0x00;                       // Reset TIMER0
        }
    }
}

/*****************************************************************************/
/* FUNCTION     : ADC_vect                                                   */
/* INPUT        : -                                                          */
/* OUTPUT       : -                                                          */
/* COMMENTS     : ISR for ADC conversion completed                           */
/*****************************************************************************/
SIGNAL(SPI_STC_vect)
{
    fSPIWR = 0;                                 // Clear SPI writing flag
}

/*****************************************************************************/
```

```
/* FUNCTION     : ADC_vect                                                    */
/* INPUT        : -                                                           */
/* OUTPUT       : -                                                           */
/* COMMENTS     : ISR for ADC conversion completed                            */
/*****************************************************************************/
SIGNAL(ADC_vect)
{
    fADC = 0;                                   // Clear AD conversion flag
}
```

CS Dispatch

```vhdl
-- VHDL Entity CS_Dispatch_lib.TOP.symbol
--
-- Created:
--          by - Yannick Salamin.UNKNOWN (AEM-1D2421F5C0D)
--          at - 16:28:25 11/11/2010
--
-- Generated by Mentor Graphics' HDL Designer(TM) 2005.3 (Build 74)
--
LIBRARY ieee;
USE ieee.std_logic_1164.all;
USE ieee.NUMERIC_STD.all;

ENTITY TOP IS
   PORT(
      CLK     : IN     std_logic;
      CS      : IN     std_logic;
      DIN     : IN     std_logic;
      CS_N    : OUT    unsigned ( 36 DOWNTO 0 );
      DOUT    : OUT    std_logic;
      FB_Addr : OUT    unsigned (5 DOWNTO 0)
   );

-- Declarations

END TOP ;

--
-- VHDL Architecture CS_Dispatch_lib.TOP.struct
--
-- Created:
--          by - Yannick Salamin.UNKNOWN (AEM-1D2421F5C0D)
--          at - 16:28:25 11/11/2010
--
-- Generated by Mentor Graphics' HDL Designer(TM) 2005.3 (Build 74)
--
LIBRARY ieee;
USE ieee.std_logic_1164.all;
USE ieee.NUMERIC_STD.all;

LIBRARY CS_Dispatch_lib;

ARCHITECTURE struct OF TOP IS

   -- Architecture declarations

   -- Internal signal declarations
   SIGNAL FB    : std_logic := '0';
   SIGNAL dbus0 : unsigned(5 DOWNTO 0);


   -- Component Declarations
   COMPONENT FB_selection
   PORT (
      CS      : IN     std_logic ;
      FB      : IN     std_logic ;
      FB_Addr : OUT    unsigned (5 DOWNTO 0)
   );
   END COMPONENT;
   COMPONENT SPI
```

```
   PORT (
      CLK   : IN     std_logic ;
      CS    : IN     std_logic ;
      DIN   : IN     std_logic ;
      DOUT  : OUT    std_logic ;
      FB    : OUT    std_logic ;
      dbus0 : OUT    unsigned (5 DOWNTO 0)
   );
   END COMPONENT;
   COMPONENT chips_selection
   PORT (
      dbus1 : IN     unsigned (5 DOWNTO 0);
      CS_N  : OUT    unsigned (36 DOWNTO 0)
   );
   END COMPONENT;

   -- Optional embedded configurations
   -- pragma synthesis_off
   FOR ALL : FB_selection USE ENTITY CS_Dispatch_lib.FB_selection;
   FOR ALL : SPI USE ENTITY CS_Dispatch_lib.SPI;
   FOR ALL : chips_selection USE ENTITY CS_Dispatch_lib.chips_selection;
   -- pragma synthesis_on


BEGIN

   -- Instance port mappings.
   U_2 : FB_selection
      PORT MAP (
         CS      => CS,
         FB      => FB,
         FB_Addr => FB_Addr
      );
   U_0 : SPI
      PORT MAP (
         CLK   => CLK,
         CS    => CS,
         DIN   => DIN,
         DOUT  => DOUT,
         FB    => FB,
         dbus0 => dbus0
      );
   U_1 : chips_selection
      PORT MAP (
         dbus1 => dbus0,
         CS_N  => CS_N
      );

END struct;
```

```
--
-- VHDL Architecture CS_Dispatch_lib.SPI.struct
--
-- Created:
--          by - Yannick Salamin.UNKNOWN (AEM-1D2421F5C0D)
--          at - 19:51:32 09/25/2010
--
-- using Mentor Graphics HDL Designer(TM) 2005.3 (Build 74)
--
LIBRARY ieee;
USE ieee.std_logic_1164.all;
USE ieee.NUMERIC_STD.all;

ENTITY SPI IS
   PORT(
      CLK   : IN     std_logic;
      CS    : IN     std_logic;
      DIN   : IN     std_logic;
      DOUT  : OUT    std_logic;
      FB    : OUT    std_logic;
      dbus0 : OUT    unsigned (5 DOWNTO 0)
   );

-- Declarations

END SPI ;

--
ARCHITECTURE struct OF SPI IS

  signal counter_int : unsigned(7 DOWNTO 0);
  signal count : natural:=0;

BEGIN

  process(CLK)

  begin
    if CS = '0' then
      if count < 8 then
        if falling_edge(CLK) then                       --  Check falling edge of clock signal
          counter_int(7-count) <= DIN;                  -- Read data signal every clock
          falling edge
          count <= count + 1;                           -- Increment counter to store next
          data
        end if;
      end if;
    else
      if count < 8 then                                 -- Check if SPI read complete
        if counter_int = 100 then                       -- Check if FB process to execute
          FB <=                                         -- FB pulse to execute FB channel
          selection
             '1',
             '0' AFTER 4 us;
          count <= 0;                                   -- Reset counter
        else
          dbus0 <= RESIZE(counter_int,dbus0'length);    -- Transmit the DAC numbre to select
          count <= 0;                                   -- Reset counter
        end if;
```

```
      end if;
      count <= 0;                                    -- Reset counter
    end if;
  end process;

END ARCHITECTURE struct;
```

```
--
-- VHDL Architecture CS_Dispatch_lib.chips_selection.struct
--
-- Created:
--          by - Yannick Salamin.UNKNOWN (AEM-1D2421F5C0D)
--          at - 19:56:34 09/25/2010
--
-- using Mentor Graphics HDL Designer(TM) 2005.3 (Build 74)
--
LIBRARY ieee;
USE ieee.std_logic_1164.all;
USE ieee.NUMERIC_STD.all;

ENTITY chips_selection IS
   PORT(
      dbus1 : IN     unsigned (5 DOWNTO 0);
      CS_N  : OUT    unsigned (36 DOWNTO 0)
   );

-- Declarations

END chips_selection ;

--
ARCHITECTURE struct OF chips_selection IS
BEGIN

  process(dbus1)
    begin
     -- chips selection, for the value 0 no DAC are selected,
         -- for the values between 1 and 37 the corresponding DAC
       -- is selected and for the value 50, every DAC is selected
     case TO_INTEGER(dbus1) is
       when 0 => CS_N <= (others => '1');
       when 1 => CS_N <= (0 => '0', others => '1');
       when 2 => CS_N <= (1 => '0', others => '1');
       when 3 => CS_N <= (2 => '0', others => '1');
       when 4 => CS_N <= (3 => '0', others => '1');
       when 5 => CS_N <= (4 => '0', others => '1');
       when 6 => CS_N <= (5 => '0', others => '1');
       when 7 => CS_N <= (6 => '0', others => '1');
       when 8 => CS_N <= (7 => '0', others => '1');
       when 9 => CS_N <= (8 => '0', others => '1');
       when 10 => CS_N <= (9 => '0', others => '1');
       when 11 => CS_N <= (10 => '0', others => '1');
       when 12 => CS_N <= (11 => '0', others => '1');
       when 13 => CS_N <= (12 => '0', others => '1');
       when 14 => CS_N <= (13 => '0', others => '1');
       when 15 => CS_N <= (14 => '0', others => '1');
       when 16 => CS_N <= (15 => '0', others => '1');
       when 17 => CS_N <= (16 => '0', others => '1');
       when 18 => CS_N <= (17 => '0', others => '1');
       when 19 => CS_N <= (18 => '0', others => '1');
       when 20 => CS_N <= (19 => '0', others => '1');
       when 21 => CS_N <= (20 => '0', others => '1');
       when 22 => CS_N <= (21 => '0', others => '1');
       when 23 => CS_N <= (22 => '0', others => '1');
```

```
      when 24 => CS_N <= (23 => '0', others => '1');
      when 25 => CS_N <= (24 => '0', others => '1');
      when 26 => CS_N <= (25 => '0', others => '1');
      when 27 => CS_N <= (26 => '0', others => '1');
      when 28 => CS_N <= (27 => '0', others => '1');
      when 29 => CS_N <= (28 => '0', others => '1');
      when 30 => CS_N <= (29 => '0', others => '1');
      when 31 => CS_N <= (30 => '0', others => '1');
      when 32 => CS_N <= (31 => '0', others => '1');
      when 33 => CS_N <= (32 => '0', others => '1');
      when 34 => CS_N <= (33 => '0', others => '1');
      when 35 => CS_N <= (34 => '0', others => '1');
      when 36 => CS_N <= (35 => '0', others => '1');
      when 37 => CS_N <= (36 => '0', others => '1');
      when others => CS_N <= (others => '1');
    end case;
  end process;


END ARCHITECTURE struct;
```

```
--
-- VHDL Architecture CS_Dispatch_lib.FB_selection.struct
--
-- Created:
--          by - Yannick Salamin.UNKNOWN (AEM-1D2421F5C0D)
--          at - 20:17:53 09/25/2010
--
-- using Mentor Graphics HDL Designer(TM) 2005.3 (Build 74)
--
LIBRARY ieee;
USE ieee.std_logic_1164.all;
USE ieee.NUMERIC_STD.all;

ENTITY FB_selection IS
   PORT(
      CS      : IN     std_logic;
      FB      : IN     std_logic;
      FB_Addr : OUT    unsigned (5 DOWNTO 0)
   );

-- Declarations

END FB_selection ;

--
ARCHITECTURE struct OF FB_selection IS

  signal address_int : unsigned(5 DOWNTO 0);
  signal flag : std_ulogic;
  signal count_int : unsigned(5 DOWNTO 0);

BEGIN

  process(FB,CS)
  begin
    if FB = '1' then                          -- Check if FB signal pulse
      FB_Addr <= (others => '0');             -- Reset counter
      count_int <= (others => '0');           -- Reset feedback channel
      flag <= '1';                            -- Set flag for FB process on
    elsif falling_edge(CS) then               -- Check falling edge of CS signal
      if flag = '1' then                      -- Check if FB process on
        if count_int < 37 then                -- Check if end of FB
          FB_Addr <= count_int;               -- Update feedback channel
          count_int <= count_int + 1;         -- Increment counter
        else
          count_int <= (others => '0');       -- Reset counter
          FB_Addr <= (others => '0');         -- Reset feedback channel
          flag <= '0';                        -- Reset FB processing flag
        end if;
      end if;
    end if;
  end process;

END ARCHITECTURE struct;
```

GUI

```
/*****************************************************************************/
/* FILENAME :   IO.c                                                         */
/* AUTHOR   :   Salamin Yannick     <yannick.salamin@gmail.com>              */
/*---------------------------------------------------------------------------*/
/* FUNCTION :   Familiarizing with the ATmega88 MCU features.                */
/*---------------------------------------------------------------------------*/
/* REVISION :   1.0 (version for ATmega88)                                   */
/*****************************************************************************/

#include "stdafx.h"
#include "Form1.h"
#include <windows.h>
#include "USB.h"

using namespace USBFT245R;

int APIENTRY _tWinMain(HINSTANCE hInstance,
                       HINSTANCE hPrevInstance,
                       LPTSTR    lpCmdLine,
                       int       nCmdShow)
{

    System::Threading::Thread::CurrentThread->ApartmentState = System::Threading::
    ApartmentState::STA;
    Application::Run(new Form1());
    return 0;
}

/*****************************************************************************/
/* FUNCTION     : Form1()                                                    */
/* INPUT        : -                                                          */
/* OUTPUT       : -                                                          */
/* COMMENTS     : Constructor of the class From1                             */
/*****************************************************************************/
Form1::Form1()
{
    InitializeComponent();                                  // Call the component
    inistialisation method
}

/*****************************************************************************/
/* FUNCTION     : Dispose(Boolean disposing)                                 */
/* INPUT        : Boolean                                                    */
/* OUTPUT       : -                                                          */
/* COMMENTS     : Constructor of the class From1                             */
/*****************************************************************************/
void Form1::Dispose(Boolean disposing)
{
    StopThread();                                           // Close the thread

    if (disposing && components)
    {
        components->Dispose();
    }
    __super::Dispose(disposing);
}

void Form1::InitializeComponent()
{
```

```
this->btnClose = (new System::Windows::Forms::Button());
this->btnSend = (new System::Windows::Forms::Button());
this->listBox1 = (new System::Windows::Forms::ListBox());
this->comboBox1 = (new System::Windows::Forms::ComboBox());
this->radioNumber = (new System::Windows::Forms::RadioButton());
this->radioDescription = (new System::Windows::Forms::RadioButton());
this->radioSerial = (new System::Windows::Forms::RadioButton());
this->groupBox1 = (new System::Windows::Forms::GroupBox());
this->textBoxAngle = (new System::Windows::Forms::TextBox());
this->label1 = (new System::Windows::Forms::Label());
this->label2 = (new System::Windows::Forms::Label());
this->groupBox2 = (new System::Windows::Forms::GroupBox());
this->radioDiffV = (new System::Windows::Forms::RadioButton());
this->radioSameV = (new System::Windows::Forms::RadioButton());
this->radioDirect = (new System::Windows::Forms::RadioButton());
this->label3 = (new System::Windows::Forms::Label());
this->label4 = (new System::Windows::Forms::Label());
this->textBoxSameV = (new System::Windows::Forms::TextBox());
this->label5 = (new System::Windows::Forms::Label());
this->textBox3 = (new System::Windows::Forms::TextBox());
this->label6 = (new System::Windows::Forms::Label());
this->textBox4 = (new System::Windows::Forms::TextBox());
this->label7 = (new System::Windows::Forms::Label());
this->textBox5 = (new System::Windows::Forms::TextBox());
this->label8 = (new System::Windows::Forms::Label());
this->textBox6 = (new System::Windows::Forms::TextBox());
this->label9 = (new System::Windows::Forms::Label());
this->textBox7 = (new System::Windows::Forms::TextBox());
this->label10 = (new System::Windows::Forms::Label());
this->textBox8 = (new System::Windows::Forms::TextBox());
this->label11 = (new System::Windows::Forms::Label());
this->textBox9 = (new System::Windows::Forms::TextBox());
this->label12 = (new System::Windows::Forms::Label());
this->textBox10 = (new System::Windows::Forms::TextBox());
this->label13 = (new System::Windows::Forms::Label());
this->textBox11 = (new System::Windows::Forms::TextBox());
this->label14 = (new System::Windows::Forms::Label());
this->textBox12 = (new System::Windows::Forms::TextBox());
this->label15 = (new System::Windows::Forms::Label());
this->textBox13 = (new System::Windows::Forms::TextBox());
this->label16 = (new System::Windows::Forms::Label());
this->textBox14 = (new System::Windows::Forms::TextBox());
this->label17 = (new System::Windows::Forms::Label());
this->textBox15 = (new System::Windows::Forms::TextBox());
this->label18 = (new System::Windows::Forms::Label());
this->textBox16 = (new System::Windows::Forms::TextBox());
this->label19 = (new System::Windows::Forms::Label());
this->textBox17 = (new System::Windows::Forms::TextBox());
this->label20 = (new System::Windows::Forms::Label());
this->textBox18 = (new System::Windows::Forms::TextBox());
this->label21 = (new System::Windows::Forms::Label());
this->textBox19 = (new System::Windows::Forms::TextBox());
this->label22 = (new System::Windows::Forms::Label());
this->textBox20 = (new System::Windows::Forms::TextBox());
this->label23 = (new System::Windows::Forms::Label());
this->textBox21 = (new System::Windows::Forms::TextBox());
this->label24 = (new System::Windows::Forms::Label());
this->textBox22 = (new System::Windows::Forms::TextBox());
this->label28 = (new System::Windows::Forms::Label());
```

```
this->textBox26 = (new System::Windows::Forms::TextBox());
this->label29 = (new System::Windows::Forms::Label());
this->textBox27 = (new System::Windows::Forms::TextBox());
this->label30 = (new System::Windows::Forms::Label());
this->textBox28 = (new System::Windows::Forms::TextBox());
this->label31 = (new System::Windows::Forms::Label());
this->textBox29 = (new System::Windows::Forms::TextBox());
this->label32 = (new System::Windows::Forms::Label());
this->textBox30 = (new System::Windows::Forms::TextBox());
this->label33 = (new System::Windows::Forms::Label());
this->textBox31 = (new System::Windows::Forms::TextBox());
this->label34 = (new System::Windows::Forms::Label());
this->textBox32 = (new System::Windows::Forms::TextBox());
this->label35 = (new System::Windows::Forms::Label());
this->textBox33 = (new System::Windows::Forms::TextBox());
this->label36 = (new System::Windows::Forms::Label());
this->textBox34 = (new System::Windows::Forms::TextBox());
this->label37 = (new System::Windows::Forms::Label());
this->textBox35 = (new System::Windows::Forms::TextBox());
this->label38 = (new System::Windows::Forms::Label());
this->textBox36 = (new System::Windows::Forms::TextBox());
this->label39 = (new System::Windows::Forms::Label());
this->textBox37 = (new System::Windows::Forms::TextBox());
this->label40 = (new System::Windows::Forms::Label());
this->textBox38 = (new System::Windows::Forms::TextBox());
this->label41 = (new System::Windows::Forms::Label());
this->textBox39 = (new System::Windows::Forms::TextBox());
this->label42 = (new System::Windows::Forms::Label());
this->textBox40 = (new System::Windows::Forms::TextBox());
this->label43 = (new System::Windows::Forms::Label());
this->textBox41 = (new System::Windows::Forms::TextBox());
this->label44 = (new System::Windows::Forms::Label());
this->textBox42 = (new System::Windows::Forms::TextBox());
this->label25 = (new System::Windows::Forms::Label());
this->groupBox2->SuspendLayout();
this->SuspendLayout();
this->eventAdd = (new System::Windows::Forms::Button());

//
// btnClose
//
this->btnClose->Location = System::Drawing::Point(269, 549);
this->btnClose->Name = S"btnClose";
this->btnClose->Size = System::Drawing::Size(75, 23);
this->btnClose->TabIndex = 1;
this->btnClose->Text = S"Exit";
this->btnClose->Click += new System::EventHandler(this, &Form1::ButtonCancel_Click);
//
// btnSend
//
this->btnSend->Location = System::Drawing::Point(173, 549);
this->btnSend->Name = S"btnSend";
this->btnSend->Size = System::Drawing::Size(75, 23);
this->btnSend->TabIndex = 2;
this->btnSend->Text = S"Write";
this->btnSend->Click += new System::EventHandler(this, &Form1::btnSend_Click);
//
// listBox1
//
```

```
this->listBox1->Location = System::Drawing::Point(217, 24);
this->listBox1->Name = S"listBox1";
this->listBox1->Size = System::Drawing::Size(116, 238);
this->listBox1->TabIndex = 3;
//
// comboBox1
//
this->comboBox1->Location = System::Drawing::Point(12, 24);
this->comboBox1->Name = S"comboBox1";
this->comboBox1->Size = System::Drawing::Size(156, 21);
this->comboBox1->TabIndex = 4;
this->comboBox1->SelectedIndexChanged += new System::EventHandler(this, &Form1::
comboBox1_SelectedIndexChanged);
//
// radioNumber
//
this->radioNumber->Location = System::Drawing::Point(28, 76);
this->radioNumber->Name = S"radioNumber";
this->radioNumber->Size = System::Drawing::Size(104, 24);
this->radioNumber->TabIndex = 5;
this->radioNumber->Text = S"Number";
this->radioNumber->CheckedChanged += new System::EventHandler(this, &Form1::
radioNumber_CheckedChanged);
//
// radioDescription
//
this->radioDescription->Location = System::Drawing::Point(28, 100);
this->radioDescription->Name = S"radioDescription";
this->radioDescription->Size = System::Drawing::Size(104, 24);
this->radioDescription->TabIndex = 6;
this->radioDescription->Text = S"Description";
this->radioDescription->CheckedChanged += new System::EventHandler(this, &Form1::
radioDescription_CheckedChanged);
//
// radioSerial
//
this->radioSerial->Location = System::Drawing::Point(28, 124);
this->radioSerial->Name = S"radioSerial";
this->radioSerial->Size = System::Drawing::Size(104, 24);
this->radioSerial->TabIndex = 7;
this->radioSerial->Text = S"Serial";
this->radioSerial->CheckedChanged += new System::EventHandler(this, &Form1::
radioSerial_CheckedChanged);
//
// groupBox1
//
this->groupBox1->Location = System::Drawing::Point(12, 60);
this->groupBox1->Name = S"groupBox1";
this->groupBox1->Size = System::Drawing::Size(156, 96);
this->groupBox1->TabIndex = 8;
this->groupBox1->TabStop = false;
this->groupBox1->Text = S"List Devices By";
//
// textBoxAngle
//
this->textBoxAngle->Enabled = false;
this->textBoxAngle->Location = System::Drawing::Point(5, 281);
this->textBoxAngle->Name = S"textBoxAngle";
this->textBoxAngle->Size = System::Drawing::Size(76, 20);
```

```
this->textBoxAngle->TabIndex = 10;
//
// label1
//
this->label1->AutoSize = true;
this->label1->Location = System::Drawing::Point(9, 8);
this->label1->Name = S"label1";
this->label1->Size = System::Drawing::Size(41, 13);
this->label1->TabIndex = 11;
this->label1->Text = S"Device";
//
// label2
//
this->label2->AutoSize = true;
this->label2->Location = System::Drawing::Point(214, 8);
this->label2->Name = S"label2";
this->label2->Size = System::Drawing::Size(74, 13);
this->label2->TabIndex = 12;
this->label2->Text = S"Incoming data";
//
// groupBox2
//
this->groupBox2->Controls->Add(this->radioDiffV);
this->groupBox2->Controls->Add(this->radioSameV);
this->groupBox2->Controls->Add(this->radioDirect);
this->groupBox2->Location = System::Drawing::Point(12, 165);
this->groupBox2->Name = S"groupBox2";
this->groupBox2->Size = System::Drawing::Size(156, 97);
this->groupBox2->TabIndex = 13;
this->groupBox2->TabStop = false;
this->groupBox2->Text = S"Angle set type";
//
// radioDiffV
//
this->radioDiffV->AutoSize = true;
this->radioDiffV->Location = System::Drawing::Point(16, 65);
this->radioDiffV->Name = S"radioDiffV";
this->radioDiffV->Size = System::Drawing::Size(138, 17);
this->radioDiffV->TabIndex = 5;
this->radioDiffV->TabStop = true;
this->radioDiffV->Text = S"Different voltage for test";
this->radioDiffV->UseVisualStyleBackColor = true;
this->radioDiffV->CheckedChanged += new System::EventHandler(this, &Form1::
radioDiffV_CheckedChanged);
//
// radioSameV
//
this->radioSameV->AutoSize = true;
this->radioSameV->Location = System::Drawing::Point(16, 42);
this->radioSameV->Name = S"radioSameV";
this->radioSameV->Size = System::Drawing::Size(125, 17);
this->radioSameV->TabIndex = 4;
this->radioSameV->TabStop = true;
this->radioSameV->Text = S"Same voltage for test";
this->radioSameV->UseVisualStyleBackColor = true;
this->radioSameV->CheckedChanged += new System::EventHandler(this, &Form1::
radioSameV_CheckedChanged);
//
// radioDirect
```

```
//
this->radioDirect->AutoSize = true;
this->radioDirect->Location = System::Drawing::Point(16, 19);
this->radioDirect->Name = S"radioDirect";
this->radioDirect->Size = System::Drawing::Size(82, 17);
this->radioDirect->TabIndex = 3;
this->radioDirect->TabStop = true;
this->radioDirect->Text = S"Direct angle";
this->radioDirect->UseVisualStyleBackColor = true;
this->radioDirect->CheckedChanged += new System::EventHandler(this, &Form1::
radioDirect_CheckedChanged);
//
// label3
//
this->label3->AutoSize = true;
this->label3->Location = System::Drawing::Point(2, 265);
this->label3->Name = S"label3";
this->label3->Size = System::Drawing::Size(34, 13);
this->label3->TabIndex = 14;
this->label3->Text = S"Angle";
//
// label4
//
this->label4->AutoSize = true;
this->label4->Location = System::Drawing::Point(2, 304);
this->label4->Name = S"label4";
this->label4->Size = System::Drawing::Size(72, 13);
this->label4->TabIndex = 16;
this->label4->Text = S"Same voltage";
//
// textBoxSameV
//
this->textBoxSameV->Location = System::Drawing::Point(5, 320);
this->textBoxSameV->Name = S"textBoxSameV";
this->textBoxSameV->Size = System::Drawing::Size(76, 20);
this->textBoxSameV->TabIndex = 15;
//
// label5
//
this->label5->AutoSize = true;
this->label5->Location = System::Drawing::Point(2, 365);
this->label5->Name = S"label5";
this->label5->Size = System::Drawing::Size(20, 13);
this->label5->TabIndex = 18;
this->label5->Text = S"V1";
//
// textBox3
//
this->textBox3->Location = System::Drawing::Point(21, 362);
this->textBox3->Name = S"textBox3";
this->textBox3->Size = System::Drawing::Size(57, 20);
this->textBox3->TabIndex = 17;
//
// label6
//
this->label6->AutoSize = true;
this->label6->Location = System::Drawing::Point(2, 391);
this->label6->Name = S"label6";
this->label6->Size = System::Drawing::Size(20, 13);
```

```
this->label6->TabIndex = 20;
this->label6->Text = S"V2";
//
// textBox4
//
this->textBox4->Location = System::Drawing::Point(21, 388);
this->textBox4->Name = S"textBox4";
this->textBox4->Size = System::Drawing::Size(57, 20);
this->textBox4->TabIndex = 19;
//
// label7
//
this->label7->AutoSize = true;
this->label7->Location = System::Drawing::Point(2, 417);
this->label7->Name = S"label7";
this->label7->Size = System::Drawing::Size(20, 13);
this->label7->TabIndex = 22;
this->label7->Text = S"V3";
//
// textBox5
//
this->textBox5->Location = System::Drawing::Point(21, 414);
this->textBox5->Name = S"textBox5";
this->textBox5->Size = System::Drawing::Size(57, 20);
this->textBox5->TabIndex = 21;
//
// label8
//
this->label8->AutoSize = true;
this->label8->Location = System::Drawing::Point(2, 443);
this->label8->Name = S"label8";
this->label8->Size = System::Drawing::Size(20, 13);
this->label8->TabIndex = 24;
this->label8->Text = S"V4";
//
// textBox6
//
this->textBox6->Location = System::Drawing::Point(21, 440);
this->textBox6->Name = S"textBox6";
this->textBox6->Size = System::Drawing::Size(57, 20);
this->textBox6->TabIndex = 23;
//
// label9
//
this->label9->AutoSize = true;
this->label9->Location = System::Drawing::Point(2, 469);
this->label9->Name = S"label9";
this->label9->Size = System::Drawing::Size(20, 13);
this->label9->TabIndex = 26;
this->label9->Text = S"V5";
//
// textBox7
//
this->textBox7->Location = System::Drawing::Point(21, 466);
this->textBox7->Name = S"textBox7";
this->textBox7->Size = System::Drawing::Size(57, 20);
this->textBox7->TabIndex = 25;
//
// label10
```

```
//
this->label10->AutoSize = true;
this->label10->Location = System::Drawing::Point(2, 495);
this->label10->Name = S"label10";
this->label10->Size = System::Drawing::Size(20, 13);
this->label10->TabIndex = 28;
this->label10->Text = S"V6";
//
// textBox8
//
this->textBox8->Location = System::Drawing::Point(21, 492);
this->textBox8->Name = S"textBox8";
this->textBox8->Size = System::Drawing::Size(57, 20);
this->textBox8->TabIndex = 27;
//
// label11
//
this->label11->AutoSize = true;
this->label11->Location = System::Drawing::Point(87, 339);
this->label11->Name = S"label11";
this->label11->Size = System::Drawing::Size(26, 13);
this->label11->TabIndex = 36;
this->label11->Text = S"V10";
//
// textBox9
//
this->textBox9->Location = System::Drawing::Point(112, 336);
this->textBox9->Name = S"textBox9";
this->textBox9->Size = System::Drawing::Size(57, 20);
this->textBox9->TabIndex = 35;
//
// label12
//
this->label12->AutoSize = true;
this->label12->Location = System::Drawing::Point(93, 313);
this->label12->Name = S"label12";
this->label12->Size = System::Drawing::Size(20, 13);
this->label12->TabIndex = 34;
this->label12->Text = S"V9";
//
// textBox10
//
this->textBox10->Location = System::Drawing::Point(112, 310);
this->textBox10->Name = S"textBox10";
this->textBox10->Size = System::Drawing::Size(57, 20);
this->textBox10->TabIndex = 33;
//
// label13
//
this->label13->AutoSize = true;
this->label13->Location = System::Drawing::Point(93, 287);
this->label13->Name = S"label13";
this->label13->Size = System::Drawing::Size(20, 13);
this->label13->TabIndex = 32;
this->label13->Text = S"V8";
//
// textBox11
//
this->textBox11->Location = System::Drawing::Point(112, 284);
```

```
this->textBox11->Name = S"textBox11";
this->textBox11->Size = System::Drawing::Size(57, 20);
this->textBox11->TabIndex = 31;
//
// label14
//
this->label14->AutoSize = true;
this->label14->Location = System::Drawing::Point(2, 520);
this->label14->Name = S"label14";
this->label14->Size = System::Drawing::Size(20, 13);
this->label14->TabIndex = 30;
this->label14->Text = S"V7";
//
// textBox12
//
this->textBox12->Location = System::Drawing::Point(21, 517);
this->textBox12->Name = S"textBox12";
this->textBox12->Size = System::Drawing::Size(57, 20);
this->textBox12->TabIndex = 29;
//
// label15
//
this->label15->AutoSize = true;
this->label15->Location = System::Drawing::Point(173, 339);
this->label15->Name = S"label15";
this->label15->Size = System::Drawing::Size(26, 13);
this->label15->TabIndex = 56;
this->label15->Text = S"V20";
//
// textBox13
//
this->textBox13->Location = System::Drawing::Point(200, 336);
this->textBox13->Name = S"textBox13";
this->textBox13->Size = System::Drawing::Size(57, 20);
this->textBox13->TabIndex = 55;
//
// label16
//
this->label16->AutoSize = true;
this->label16->Location = System::Drawing::Point(175, 313);
this->label16->Name = S"label16";
this->label16->Size = System::Drawing::Size(26, 13);
this->label16->TabIndex = 54;
this->label16->Text = S"V19";
//
// textBox14
//
this->textBox14->Location = System::Drawing::Point(200, 310);
this->textBox14->Name = S"textBox14";
this->textBox14->Size = System::Drawing::Size(57, 20);
this->textBox14->TabIndex = 53;
//
// label17
//
this->label17->AutoSize = true;
this->label17->Location = System::Drawing::Point(175, 287);
this->label17->Name = S"label17";
this->label17->Size = System::Drawing::Size(26, 13);
this->label17->TabIndex = 52;
```

```
this->label17->Text = S"V18";
//
// textBox15
//
this->textBox15->Location = System::Drawing::Point(200, 284);
this->textBox15->Name = S"textBox15";
this->textBox15->Size = System::Drawing::Size(57, 20);
this->textBox15->TabIndex = 51;
//
// label18
//
this->label18->AutoSize = true;
this->label18->Location = System::Drawing::Point(87, 520);
this->label18->Name = S"label18";
this->label18->Size = System::Drawing::Size(26, 13);
this->label18->TabIndex = 50;
this->label18->Text = S"V17";
//
// textBox16
//
this->textBox16->Location = System::Drawing::Point(112, 517);
this->textBox16->Name = S"textBox16";
this->textBox16->Size = System::Drawing::Size(57, 20);
this->textBox16->TabIndex = 49;
//
// label19
//
this->label19->AutoSize = true;
this->label19->Location = System::Drawing::Point(87, 495);
this->label19->Name = S"label19";
this->label19->Size = System::Drawing::Size(26, 13);
this->label19->TabIndex = 48;
this->label19->Text = S"V16";
//
// textBox17
//
this->textBox17->Location = System::Drawing::Point(112, 492);
this->textBox17->Name = S"textBox17";
this->textBox17->Size = System::Drawing::Size(57, 20);
this->textBox17->TabIndex = 47;
//
// label20
//
this->label20->AutoSize = true;
this->label20->Location = System::Drawing::Point(87, 469);
this->label20->Name = S"label20";
this->label20->Size = System::Drawing::Size(26, 13);
this->label20->TabIndex = 46;
this->label20->Text = S"V15";
//
// textBox18
//
this->textBox18->Location = System::Drawing::Point(112, 466);
this->textBox18->Name = S"textBox18";
this->textBox18->Size = System::Drawing::Size(57, 20);
this->textBox18->TabIndex = 45;
//
// label21
//
```

```
this->label21->AutoSize = true;
this->label21->Location = System::Drawing::Point(87, 443);
this->label21->Name = S"label21";
this->label21->Size = System::Drawing::Size(26, 13);
this->label21->TabIndex = 44;
this->label21->Text = S"V14";
//
// textBox19
//
this->textBox19->Location = System::Drawing::Point(112, 440);
this->textBox19->Name = S"textBox19";
this->textBox19->Size = System::Drawing::Size(57, 20);
this->textBox19->TabIndex = 43;
//
// label22
//
this->label22->AutoSize = true;
this->label22->Location = System::Drawing::Point(87, 417);
this->label22->Name = S"label22";
this->label22->Size = System::Drawing::Size(26, 13);
this->label22->TabIndex = 42;
this->label22->Text = S"V13";
//
// textBox20
//
this->textBox20->Location = System::Drawing::Point(112, 414);
this->textBox20->Name = S"textBox20";
this->textBox20->Size = System::Drawing::Size(57, 20);
this->textBox20->TabIndex = 41;
//
// label23
//
this->label23->AutoSize = true;
this->label23->Location = System::Drawing::Point(87, 391);
this->label23->Name = S"label23";
this->label23->Size = System::Drawing::Size(26, 13);
this->label23->TabIndex = 40;
this->label23->Text = S"V12";
//
// textBox21
//
this->textBox21->Location = System::Drawing::Point(112, 388);
this->textBox21->Name = S"textBox21";
this->textBox21->Size = System::Drawing::Size(57, 20);
this->textBox21->TabIndex = 39;
//
// label24
//
this->label24->AutoSize = true;
this->label24->Location = System::Drawing::Point(87, 365);
this->label24->Name = S"label24";
this->label24->Size = System::Drawing::Size(26, 13);
this->label24->TabIndex = 38;
this->label24->Text = S"V11";
//
// textBox22
//
this->textBox22->Location = System::Drawing::Point(112, 362);
this->textBox22->Name = S"textBox22";
```

```
this->textBox22->Size = System::Drawing::Size(57, 20);
this->textBox22->TabIndex = 37;
//
// label28
//
this->label28->AutoSize = true;
this->label28->Location = System::Drawing::Point(262, 520);
this->label28->Name = S"label28";
this->label28->Size = System::Drawing::Size(26, 13);
this->label28->TabIndex = 90;
this->label28->Text = S"V37";
//
// textBox26
//
this->textBox26->Location = System::Drawing::Point(287, 517);
this->textBox26->Name = S"textBox26";
this->textBox26->Size = System::Drawing::Size(57, 20);
this->textBox26->TabIndex = 89;
//
// label29
//
this->label29->AutoSize = true;
this->label29->Location = System::Drawing::Point(262, 495);
this->label29->Name = S"label29";
this->label29->Size = System::Drawing::Size(26, 13);
this->label29->TabIndex = 88;
this->label29->Text = S"V36";
//
// textBox27
//
this->textBox27->Location = System::Drawing::Point(287, 492);
this->textBox27->Name = S"textBox27";
this->textBox27->Size = System::Drawing::Size(57, 20);
this->textBox27->TabIndex = 87;
//
// label30
//
this->label30->AutoSize = true;
this->label30->Location = System::Drawing::Point(262, 469);
this->label30->Name = S"label30";
this->label30->Size = System::Drawing::Size(26, 13);
this->label30->TabIndex = 86;
this->label30->Text = S"V35";
//
// textBox28
//
this->textBox28->Location = System::Drawing::Point(287, 466);
this->textBox28->Name = S"textBox28";
this->textBox28->Size = System::Drawing::Size(57, 20);
this->textBox28->TabIndex = 85;
//
// label31
//
this->label31->AutoSize = true;
this->label31->Location = System::Drawing::Point(262, 443);
this->label31->Name = S"label31";
this->label31->Size = System::Drawing::Size(26, 13);
this->label31->TabIndex = 84;
this->label31->Text = S"V34";
```

```
//
// textBox29
//
this->textBox29->Location = System::Drawing::Point(287, 440);
this->textBox29->Name = S"textBox29";
this->textBox29->Size = System::Drawing::Size(57, 20);
this->textBox29->TabIndex = 83;
//
// label32
//
this->label32->AutoSize = true;
this->label32->Location = System::Drawing::Point(262, 417);
this->label32->Name = S"label32";
this->label32->Size = System::Drawing::Size(26, 13);
this->label32->TabIndex = 82;
this->label32->Text = S"V33";
//
// textBox30
//
this->textBox30->Location = System::Drawing::Point(287, 414);
this->textBox30->Name = S"textBox30";
this->textBox30->Size = System::Drawing::Size(57, 20);
this->textBox30->TabIndex = 81;
//
// label33
//
this->label33->AutoSize = true;
this->label33->Location = System::Drawing::Point(262, 391);
this->label33->Name = S"label33";
this->label33->Size = System::Drawing::Size(26, 13);
this->label33->TabIndex = 80;
this->label33->Text = S"V32";
//
// textBox31
//
this->textBox31->Location = System::Drawing::Point(287, 388);
this->textBox31->Name = S"textBox31";
this->textBox31->Size = System::Drawing::Size(57, 20);
this->textBox31->TabIndex = 79;
//
// label34
//
this->label34->AutoSize = true;
this->label34->Location = System::Drawing::Point(262, 365);
this->label34->Name = S"label34";
this->label34->Size = System::Drawing::Size(26, 13);
this->label34->TabIndex = 78;
this->label34->Text = S"V31";
//
// textBox32
//
this->textBox32->Location = System::Drawing::Point(287, 362);
this->textBox32->Name = S"textBox32";
this->textBox32->Size = System::Drawing::Size(57, 20);
this->textBox32->TabIndex = 77;
//
// label35
//
this->label35->AutoSize = true;
```

```
this->label35->Location = System::Drawing::Point(262, 339);
this->label35->Name = S"label35";
this->label35->Size = System::Drawing::Size(26, 13);
this->label35->TabIndex = 76;
this->label35->Text = S"V30";
//
// textBox33
//
this->textBox33->Location = System::Drawing::Point(287, 336);
this->textBox33->Name = S"textBox33";
this->textBox33->Size = System::Drawing::Size(57, 20);
this->textBox33->TabIndex = 75;
//
// label36
//
this->label36->AutoSize = true;
this->label36->Location = System::Drawing::Point(262, 313);
this->label36->Name = S"label36";
this->label36->Size = System::Drawing::Size(26, 13);
this->label36->TabIndex = 74;
this->label36->Text = S"V29";
//
// textBox34
//
this->textBox34->Location = System::Drawing::Point(287, 310);
this->textBox34->Name = S"textBox34";
this->textBox34->Size = System::Drawing::Size(57, 20);
this->textBox34->TabIndex = 73;
//
// label37
//
this->label37->AutoSize = true;
this->label37->Location = System::Drawing::Point(262, 287);
this->label37->Name = S"label37";
this->label37->Size = System::Drawing::Size(26, 13);
this->label37->TabIndex = 72;
this->label37->Text = S"V28";
//
// textBox35
//
this->textBox35->Location = System::Drawing::Point(287, 284);
this->textBox35->Name = S"textBox35";
this->textBox35->Size = System::Drawing::Size(57, 20);
this->textBox35->TabIndex = 71;
//
// label38
//
this->label38->AutoSize = true;
this->label38->Location = System::Drawing::Point(175, 520);
this->label38->Name = S"label38";
this->label38->Size = System::Drawing::Size(26, 13);
this->label38->TabIndex = 70;
this->label38->Text = S"V27";
//
// textBox36
//
this->textBox36->Location = System::Drawing::Point(200, 517);
this->textBox36->Name = S"textBox36";
this->textBox36->Size = System::Drawing::Size(57, 20);
```

```
this->textBox36->TabIndex = 69;
//
// label39
//
this->label39->AutoSize = true;
this->label39->Location = System::Drawing::Point(175, 495);
this->label39->Name = S"label39";
this->label39->Size = System::Drawing::Size(26, 13);
this->label39->TabIndex = 68;
this->label39->Text = S"V26";
//
// textBox37
//
this->textBox37->Location = System::Drawing::Point(200, 492);
this->textBox37->Name = S"textBox37";
this->textBox37->Size = System::Drawing::Size(57, 20);
this->textBox37->TabIndex = 67;
//
// label40
//
this->label40->AutoSize = true;
this->label40->Location = System::Drawing::Point(175, 469);
this->label40->Name = S"label40";
this->label40->Size = System::Drawing::Size(26, 13);
this->label40->TabIndex = 66;
this->label40->Text = S"V25";
//
// textBox38
//
this->textBox38->Location = System::Drawing::Point(200, 466);
this->textBox38->Name = S"textBox38";
this->textBox38->Size = System::Drawing::Size(57, 20);
this->textBox38->TabIndex = 65;
//
// label41
//
this->label41->AutoSize = true;
this->label41->Location = System::Drawing::Point(175, 443);
this->label41->Name = S"label41";
this->label41->Size = System::Drawing::Size(26, 13);
this->label41->TabIndex = 64;
this->label41->Text = S"V24";
//
// textBox39
//
this->textBox39->Location = System::Drawing::Point(200, 440);
this->textBox39->Name = S"textBox39";
this->textBox39->Size = System::Drawing::Size(57, 20);
this->textBox39->TabIndex = 63;
//
// label42
//
this->label42->AutoSize = true;
this->label42->Location = System::Drawing::Point(175, 417);
this->label42->Name = S"label42";
this->label42->Size = System::Drawing::Size(26, 13);
this->label42->TabIndex = 62;
this->label42->Text = S"V23";
//
```

```
// textBox40
//
this->textBox40->Location = System::Drawing::Point(200, 414);
this->textBox40->Name = S"textBox40";
this->textBox40->Size = System::Drawing::Size(57, 20);
this->textBox40->TabIndex = 61;
//
// label43
//
this->label43->AutoSize = true;
this->label43->Location = System::Drawing::Point(175, 391);
this->label43->Name = S"label43";
this->label43->Size = System::Drawing::Size(26, 13);
this->label43->TabIndex = 60;
this->label43->Text = S"V22";
//
// textBox41
//
this->textBox41->Location = System::Drawing::Point(200, 388);
this->textBox41->Name = S"textBox41";
this->textBox41->Size = System::Drawing::Size(57, 20);
this->textBox41->TabIndex = 59;
//
// label44
//
this->label44->AutoSize = true;
this->label44->Location = System::Drawing::Point(175, 365);
this->label44->Name = S"label44";
this->label44->Size = System::Drawing::Size(26, 13);
this->label44->TabIndex = 58;
this->label44->Text = S"V21";
//
// textBox42
//
this->textBox42->Location = System::Drawing::Point(200, 362);
this->textBox42->Name = S"textBox42";
this->textBox42->Size = System::Drawing::Size(57, 20);
this->textBox42->TabIndex = 57;
//
// label25
//
this->label25->AutoSize = true;
this->label25->Location = System::Drawing::Point(2, 346);
this->label25->Name = S"label25";
this->label25->Size = System::Drawing::Size(85, 13);
this->label25->TabIndex = 91;
this->label25->Text = S"Different voltage";
//
// Form1
//
this->AutoScaleBaseSize = System::Drawing::Size(5, 13);
this->ClientSize = System::Drawing::Size(355, 584);
this->Controls->Add(this->label25);
this->Controls->Add(this->label28);
this->Controls->Add(this->textBox26);
this->Controls->Add(this->label29);
this->Controls->Add(this->textBox27);
this->Controls->Add(this->label30);
this->Controls->Add(this->textBox28);
```

```
this->Controls->Add(this->label31);
this->Controls->Add(this->textBox29);
this->Controls->Add(this->label32);
this->Controls->Add(this->textBox30);
this->Controls->Add(this->label33);
this->Controls->Add(this->textBox31);
this->Controls->Add(this->label34);
this->Controls->Add(this->textBox32);
this->Controls->Add(this->label35);
this->Controls->Add(this->textBox33);
this->Controls->Add(this->label36);
this->Controls->Add(this->textBox34);
this->Controls->Add(this->label37);
this->Controls->Add(this->textBox35);
this->Controls->Add(this->label38);
this->Controls->Add(this->textBox36);
this->Controls->Add(this->label39);
this->Controls->Add(this->textBox37);
this->Controls->Add(this->label40);
this->Controls->Add(this->textBox38);
this->Controls->Add(this->label41);
this->Controls->Add(this->textBox39);
this->Controls->Add(this->label42);
this->Controls->Add(this->textBox40);
this->Controls->Add(this->label43);
this->Controls->Add(this->textBox41);
this->Controls->Add(this->label44);
this->Controls->Add(this->textBox42);
this->Controls->Add(this->label15);
this->Controls->Add(this->textBox13);
this->Controls->Add(this->label16);
this->Controls->Add(this->textBox14);
this->Controls->Add(this->label17);
this->Controls->Add(this->textBox15);
this->Controls->Add(this->label18);
this->Controls->Add(this->textBox16);
this->Controls->Add(this->label19);
this->Controls->Add(this->textBox17);
this->Controls->Add(this->label20);
this->Controls->Add(this->textBox18);
this->Controls->Add(this->label21);
this->Controls->Add(this->textBox19);
this->Controls->Add(this->label22);
this->Controls->Add(this->textBox20);
this->Controls->Add(this->label23);
this->Controls->Add(this->textBox21);
this->Controls->Add(this->label24);
this->Controls->Add(this->textBox22);
this->Controls->Add(this->label11);
this->Controls->Add(this->textBox9);
this->Controls->Add(this->label12);
this->Controls->Add(this->textBox10);
this->Controls->Add(this->label13);
this->Controls->Add(this->textBox11);
this->Controls->Add(this->label14);
this->Controls->Add(this->textBox12);
this->Controls->Add(this->label10);
this->Controls->Add(this->textBox8);
this->Controls->Add(this->label9);
```

```
    this->Controls->Add(this->textBox7);
    this->Controls->Add(this->label8);
    this->Controls->Add(this->textBox6);
    this->Controls->Add(this->label7);
    this->Controls->Add(this->textBox5);
    this->Controls->Add(this->label6);
    this->Controls->Add(this->textBox4);
    this->Controls->Add(this->label5);
    this->Controls->Add(this->textBox3);
    this->Controls->Add(this->label4);
    this->Controls->Add(this->textBoxSameV);
    this->Controls->Add(this->label3);
    this->Controls->Add(this->groupBox2);
    this->Controls->Add(this->label2);
    this->Controls->Add(this->label1);
    this->Controls->Add(this->radioSerial);
    this->Controls->Add(this->radioDescription);
    this->Controls->Add(this->radioNumber);
    this->Controls->Add(this->comboBox1);
    this->Controls->Add(this->listBox1);
    this->Controls->Add(this->btnSend);
    this->Controls->Add(this->btnClose);
    this->Controls->Add(this->groupBox1);
    this->Controls->Add(this->textBoxAngle);
    this->Location = System::Drawing::Point(56, 48);
    this->Name = S"Form1";
    this->Text = S"FTDI Loopback Test";
    this->Load += new System::EventHandler(this, &Form1::Form1_Load);
    this->groupBox2->ResumeLayout(false);
    this->groupBox2->PerformLayout();
    this->ResumeLayout(false);
    this->PerformLayout();
}

void Form1::ReadingProc()
{
    ArrayList * palReadData;
    palReadData = new ArrayList();
    TimeSpan waitTime = TimeSpan(0, 0, 1);  // 1 second timeout
    static char c = 0;
    char* pstr6 = &c;
    FT_STATUS status;
    int i = 0;
    String* s;
    float data;

    while(bContinue)
    {
        DWORD dwRead, dwRXBytes;
        Byte b;
        NumberFormatInfo*   provider = new NumberFormatInfo( );

        WaitForSingleObject(hEvent, -1);
        if(handle)
        {
            status = FT_GetQueueStatus(handle, &dwRead);
            if(status != FT_OK)
            {
                MessageBox::Show("GError");
```

```
                continue;
            }

            for(int i=0;i<37*3+3;i++)
            {
                buf[i] = 0;
            }
            i = 0;

            while(dwRead && bContinue)
            {
                status = FT_Read(handle, &b, 1, &dwRXBytes);
                if(status != FT_OK)
                {
                    MessageBox::Show("RError");
                    continue;
                }
                else
                {
                    s = Convert::ToString(b);

                    buf[i] = b;
                    i++;
                }
                status = FT_GetQueueStatus(handle, &dwRead);
            }
        }

        Thread::Sleep(0);
    }

    if(handle)
    {
        FT_Close(handle);
    }
}

void Form1::setVoltageTextBox(bool b)
{
    textBox3->Enabled = b;
    textBox4->Enabled = b;
    textBox5->Enabled = b;
    textBox6->Enabled = b;
    textBox7->Enabled = b;
    textBox8->Enabled = b;
    textBox9->Enabled = b;
    textBox10->Enabled = b;
    textBox11->Enabled = b;
    textBox12->Enabled = b;
    textBox13->Enabled = b;
    textBox14->Enabled = b;
    textBox15->Enabled = b;
    textBox16->Enabled = b;
    textBox17->Enabled = b;
    textBox18->Enabled = b;
    textBox19->Enabled = b;
    textBox20->Enabled = b;
    textBox21->Enabled = b;
    textBox22->Enabled = b;
```

```
    textBox26->Enabled = b;
    textBox27->Enabled = b;
    textBox28->Enabled = b;
    textBox29->Enabled = b;
    textBox30->Enabled = b;
    textBox31->Enabled = b;
    textBox32->Enabled = b;
    textBox33->Enabled = b;
    textBox34->Enabled = b;
    textBox35->Enabled = b;
    textBox36->Enabled = b;
    textBox37->Enabled = b;
    textBox38->Enabled = b;
    textBox39->Enabled = b;
    textBox40->Enabled = b;
    textBox41->Enabled = b;
    textBox42->Enabled = b;
}
```

```
#pragma once
#include <windows.h>
#include <iostream>

namespace USBFT245R
{
    using namespace System;
    using namespace System::ComponentModel;
    using namespace System::Collections;
    using namespace System::Windows::Forms;
    using namespace System::Data;
    using namespace System::Drawing;
    using namespace System::Threading;
    using namespace System::Text;
    using namespace System::Globalization;
    using namespace System::Runtime::InteropServices;
    using namespace std;

    const UInt32 FT_LIST_NUMBER_ONLY = 0x80000000;
    const UInt32 FT_LIST_BY_INDEX   = 0x40000000;
    const UInt32 FT_LIST_ALL            = 0x20000000;
    const UInt32 FT_OPEN_BY_SERIAL_NUMBER = 1;
    const UInt32 FT_OPEN_BY_DESCRIPTION    = 2;

    const UInt32 FT_EVENT_RXCHAR        = 1;
    const UInt32 FT_EVENT_MODEM_STATUS  = 2;

    #define FT_PREFIX [DllImport("FTD2XX.dll")]

    enum {
        FT_OK,
        FT_INVALID_HANDLE,
        FT_DEVICE_NOT_FOUND,
        FT_DEVICE_NOT_OPENED,
        FT_IO_ERROR,
        FT_INSUFFICIENT_RESOURCES,
        FT_INVALID_PARAMETER,
        FT_INVALID_BAUD_RATE,

        FT_DEVICE_NOT_OPENED_FOR_ERASE,
        FT_DEVICE_NOT_OPENED_FOR_WRITE,
        FT_FAILED_TO_WRITE_DEVICE,
        FT_EEPROM_READ_FAILED,
        FT_EEPROM_WRITE_FAILED,
        FT_EEPROM_ERASE_FAILED,
        FT_EEPROM_NOT_PRESENT,
        FT_EEPROM_NOT_PROGRAMMED,
        FT_INVALID_ARGS,
        FT_NOT_SUPPORTED,
        FT_OTHER_ERROR
    };

    typedef void * FT_HANDLE;
    typedef unsigned long DWORD;
    typedef unsigned long FT_STATUS;
    typedef void * LPVOID;
    typedef void * PVOID;
    typedef DWORD * LPDWORD;
    typedef DWORD ULONG;
```

```
typedef unsigned short USHORT;
typedef unsigned char UCHAR;
typedef unsigned short WORD;
typedef WORD * LPWORD;
typedef unsigned char UCHAR;
typedef UCHAR * PUCHAR;
typedef char CHAR;
typedef CHAR * PCHAR;
typedef ULONG FT_DEVICE;
typedef void *HANDLE;
typedef int BOOL;
#define FALSE   0
#define TRUE    1

// as c++. net is a managed application and our ftd2xx.dll is unmanaged code you must
declare the functions here explicitly
// to allow you to call them within the application. An include file and the .lib file
simply wont work with c++.net. Its
// a similar problem in c#.
// see http://www.codeguru.com/Cpp/COM-Tech/complus/managed/article.php/c3947/ for more
on this.
// I have only included these 4 functions in this to show you how to do this. For other
functions that you require similar
// declerations will need to go here.


FT_PREFIX FT_STATUS FT_Open(int deviceNumber, FT_HANDLE * pHandle);
FT_PREFIX FT_STATUS FT_OpenEx(PVOID pArg1, DWORD Flags, FT_HANDLE *pHandle);
FT_PREFIX FT_STATUS FT_ListDevices(PVOID pArg1, PVOID pArg2, DWORD Flags);
FT_PREFIX FT_STATUS FT_ListDevices(UInt32 pvArg1, void * pvArg2, UInt32 dwFlags);   //
FT_ListDevcies by serial number or description by index only
FT_PREFIX FT_STATUS FT_Close(FT_HANDLE ftHandle);
FT_PREFIX FT_STATUS FT_Read(FT_HANDLE ftHandle, LPVOID lpBuffer, DWORD nBufferSize,
LPDWORD lpBytesReturned);
FT_PREFIX FT_STATUS FT_Write(FT_HANDLE ftHandle, LPVOID lpBuffer, DWORD nBufferSize,
LPDWORD lpBytesWritten);
FT_PREFIX FT_STATUS FT_SetBaudRate(FT_HANDLE ftHandle,  ULONG BaudRate);
FT_PREFIX FT_STATUS FT_SetDivisor(FT_HANDLE ftHandle,USHORT Divisor);
FT_PREFIX FT_STATUS FT_SetDataCharacteristics(FT_HANDLE ftHandle, UCHAR WordLength, UCHAR
 StopBits, UCHAR Parity);
FT_PREFIX FT_STATUS FT_SetFlowControl(FT_HANDLE ftHandle, USHORT FlowControl, UCHAR
XonChar, UCHAR XoffChar );
FT_PREFIX FT_STATUS FT_ResetDevice(FT_HANDLE ftHandle);
FT_PREFIX FT_STATUS FT_SetDtr(FT_HANDLE ftHandle);
FT_PREFIX FT_STATUS FT_ClrDtr(FT_HANDLE ftHandle);
FT_PREFIX FT_STATUS FT_SetRts(FT_HANDLE ftHandle);
FT_PREFIX FT_STATUS FT_ClrRts(FT_HANDLE ftHandle);
FT_PREFIX FT_STATUS FT_GetModemStatus(FT_HANDLE ftHandle,   ULONG *pModemStatus);
FT_PREFIX FT_STATUS FT_SetChars(FT_HANDLE ftHandle, UCHAR EventChar, UCHAR
EventCharEnabled, UCHAR ErrorChar, UCHAR ErrorCharEnabled);
FT_PREFIX FT_STATUS FT_Purge(FT_HANDLE ftHandle, ULONG Mask);
FT_PREFIX FT_STATUS FT_SetTimeouts(FT_HANDLE ftHandle,  ULONG ReadTimeout,  ULONG
WriteTimeout);
FT_PREFIX FT_STATUS FT_GetQueueStatus(FT_HANDLE ftHandle, DWORD *dwRxBytes);
FT_PREFIX FT_STATUS FT_SetEventNotification(FT_HANDLE ftHandle, DWORD Mask, PVOID Param );
FT_PREFIX FT_STATUS FT_GetStatus(FT_HANDLE ftHandle, DWORD *dwRxBytes, DWORD *dwTxBytes,
DWORD *dwEventDWord);
FT_PREFIX FT_STATUS FT_SetBreakOn(FT_HANDLE ftHandle);
FT_PREFIX FT_STATUS FT_SetBreakOff(FT_HANDLE ftHandle);
```

```
    FT_PREFIX FT_STATUS FT_SetWaitMask(FT_HANDLE ftHandle, DWORD Mask);
    FT_PREFIX FT_STATUS FT_WaitOnMask(FT_HANDLE ftHandle, DWORD *Mask);
    FT_PREFIX FT_STATUS FT_GetEventStatus(FT_HANDLE ftHandle, DWORD *dwEventDWord);
    FT_PREFIX FT_STATUS FT_ReadEE(FT_HANDLE ftHandle, DWORD dwWordOffset, LPWORD lpwValu);
    FT_PREFIX FT_STATUS FT_WriteEE(FT_HANDLE ftHandle,  DWORD dwWordOffset, WORD wValue);
    FT_PREFIX FT_STATUS FT_EraseEE(FT_HANDLE ftHandle);
// Missed out the programming stuff +++

    FT_PREFIX FT_STATUS  FT_EE_UASize(FT_HANDLE ftHandle, LPDWORD lpdwSize);
    FT_PREFIX FT_STATUS  FT_EE_UAWrite(FT_HANDLE ftHandle, PUCHAR pucData, DWORD dwDataLen  );
    FT_PREFIX FT_STATUS  FT_EE_UARead(FT_HANDLE ftHandle, PUCHAR pucData, DWORD dwDataLen,
    LPDWORD lpdwBytesRead);
    FT_PREFIX FT_STATUS  FT_SetLatencyTimer(FT_HANDLE ftHandle, UCHAR ucLatency);
    FT_PREFIX FT_STATUS  FT_GetLatencyTimer(FT_HANDLE ftHandle, PUCHAR pucLatency);
    FT_PREFIX FT_STATUS  FT_SetBitMode(FT_HANDLE ftHandle, UCHAR ucMask, UCHAR ucEnable);
    FT_PREFIX FT_STATUS  FT_GetBitMode(FT_HANDLE ftHandle, PUCHAR pucMode);
    FT_PREFIX FT_STATUS  FT_SetUSBParameters(FT_HANDLE ftHandle, ULONG ulInTransferSize,
    ULONG ulOutTransferSize);
    FT_PREFIX FT_STATUS  FT_GetDeviceInfo(FT_HANDLE ftHandle, FT_DEVICE *lpftDevice, LPDWORD
    lpdwID, PCHAR SerialNumber, PCHAR Description, LPVOID Dummy);
    FT_PREFIX FT_STATUS  FT_StopInTask(FT_HANDLE ftHandle);
    FT_PREFIX FT_STATUS  FT_RestartInTask(FT_HANDLE ftHandle);
    FT_PREFIX FT_STATUS  FT_SetResetPipeRetryCount(FT_HANDLE ftHandle, DWORD dwCount);
    FT_PREFIX FT_STATUS  FT_ResetPort(FT_HANDLE ftHandle);


    // need these kernel functions for the Event Handling stuff
    [DllImport("Kernel32.dll")] DWORD WaitForSingleObject(HANDLE hHandle,  DWORD
    dwMilliseconds);
    [DllImport("Kernel32.dll")] HANDLE CreateEvent(void * pNULL, BOOL bManualReset, BOOL
    bInitialState, char * pcNULL);
    [DllImport("Kernel32.dll")] BOOL SetEvent(HANDLE hEvent);
    // missed out the W32 stuff as well



    FT_HANDLE handle;
    HANDLE hEvent;
    HANDLE DEvent;

    char buf[(37*3)+3];



    /// <summary>
    /// Summary for Form1
    ///
    /// WARNING: If you change the name of this class, you will need to change the
    ///          'Resource File Name' property for the managed resource compiler tool
    ///          associated with all .resx files this class depends on.  Otherwise,
    ///          the designers will not be able to interact properly with localized
    ///          resources associated with this form.
    /// </summary>

    public __delegate void addItemsEventHandler();


    public __gc class Form1 : public System::Windows::Forms::Form
    {
```

```
public:
    Form1(void);

    public __event addItemsEventHandler* addItemsEvent;

protected:
    void Dispose(bool disposing);

private:
    System::Windows::Forms::Button*  btnClose;
    System::Windows::Forms::Button*  btnSend;
    System::Windows::Forms::Button*  eventAdd;

    System::Threading::Thread* thrdReader;

    System::Windows::Forms::ListBox*  listBox1;

    System::Windows::Forms::ComboBox* comboBox1;

    System::ComponentModel::Container* components;

    System::Windows::Forms::GroupBox* groupBox1;
    System::Windows::Forms::GroupBox* groupBox2;

    System::Windows::Forms::RadioButton*  radioNumber;
    System::Windows::Forms::RadioButton*  radioDescription;
    System::Windows::Forms::RadioButton*  radioSerial;
    System::Windows::Forms::RadioButton*  radioDirect;
    System::Windows::Forms::RadioButton*  radioDiffV;
    System::Windows::Forms::RadioButton*  radioSameV;

    System::Windows::Forms::Label*  label1;
    System::Windows::Forms::Label*  label2;
    System::Windows::Forms::Label*  label3;
    System::Windows::Forms::Label*  label4;
    System::Windows::Forms::Label*  label5;
    System::Windows::Forms::Label*  label6;
    System::Windows::Forms::Label*  label7;
    System::Windows::Forms::Label*  label8;
    System::Windows::Forms::Label*  label9;
    System::Windows::Forms::Label*  label10;
    System::Windows::Forms::Label*  label11;
    System::Windows::Forms::Label*  label12;
    System::Windows::Forms::Label*  label13;
    System::Windows::Forms::Label*  label14;
    System::Windows::Forms::Label*  label15;
    System::Windows::Forms::Label*  label16;
    System::Windows::Forms::Label*  label17;
    System::Windows::Forms::Label*  label18;
    System::Windows::Forms::Label*  label19;
    System::Windows::Forms::Label*  label20;
    System::Windows::Forms::Label*  label21;
    System::Windows::Forms::Label*  label22;
    System::Windows::Forms::Label*  label23;
    System::Windows::Forms::Label*  label24;
    System::Windows::Forms::Label*  label25;
    System::Windows::Forms::Label*  label28;
    System::Windows::Forms::Label*  label29;
    System::Windows::Forms::Label*  label30;
```

```
System::Windows::Forms::Label*  label31;
System::Windows::Forms::Label*  label32;
System::Windows::Forms::Label*  label33;
System::Windows::Forms::Label*  label34;
System::Windows::Forms::Label*  label35;
System::Windows::Forms::Label*  label36;
System::Windows::Forms::Label*  label37;
System::Windows::Forms::Label*  label38;
System::Windows::Forms::Label*  label39;
System::Windows::Forms::Label*  label40;
System::Windows::Forms::Label*  label41;
System::Windows::Forms::Label*  label42;
System::Windows::Forms::Label*  label43;
System::Windows::Forms::Label*  label44;

System::Windows::Forms::TextBox*  textBoxAngle;
System::Windows::Forms::TextBox*  textBoxSameV;
System::Windows::Forms::TextBox*  textBox3;
System::Windows::Forms::TextBox*  textBox4;
System::Windows::Forms::TextBox*  textBox5;
System::Windows::Forms::TextBox*  textBox6;
System::Windows::Forms::TextBox*  textBox7;
System::Windows::Forms::TextBox*  textBox8;
System::Windows::Forms::TextBox*  textBox9;
System::Windows::Forms::TextBox*  textBox10;
System::Windows::Forms::TextBox*  textBox11;
System::Windows::Forms::TextBox*  textBox12;
System::Windows::Forms::TextBox*  textBox13;
System::Windows::Forms::TextBox*  textBox14;
System::Windows::Forms::TextBox*  textBox15;
System::Windows::Forms::TextBox*  textBox16;
System::Windows::Forms::TextBox*  textBox17;
System::Windows::Forms::TextBox*  textBox18;
System::Windows::Forms::TextBox*  textBox19;
System::Windows::Forms::TextBox*  textBox20;
System::Windows::Forms::TextBox*  textBox21;
System::Windows::Forms::TextBox*  textBox22;
System::Windows::Forms::TextBox*  textBox26;
System::Windows::Forms::TextBox*  textBox27;
System::Windows::Forms::TextBox*  textBox28;
System::Windows::Forms::TextBox*  textBox29;
System::Windows::Forms::TextBox*  textBox30;
System::Windows::Forms::TextBox*  textBox31;
System::Windows::Forms::TextBox*  textBox32;
System::Windows::Forms::TextBox*  textBox33;
System::Windows::Forms::TextBox*  textBox34;
System::Windows::Forms::TextBox*  textBox35;
System::Windows::Forms::TextBox*  textBox36;
System::Windows::Forms::TextBox*  textBox37;
System::Windows::Forms::TextBox*  textBox38;
System::Windows::Forms::TextBox*  textBox39;
System::Windows::Forms::TextBox*  textBox40;
System::Windows::Forms::TextBox*  textBox41;
System::Windows::Forms::TextBox*  textBox42;

bool bContinue;
UInt32 dwOpenFlags;
ManualResetEvent * ev;
```

```
/// <summary>
/// Required method for Designer support - do not modify
/// the contents of this method with the code editor.
/// </summary>
void InitializeComponent(void);
void ReadingProc();
void setVoltageTextBox(bool);


System::Void ButtonCancel_Click(System::Object *  sender, System::EventArgs *  e)
{
    Application::Exit();
}

System::Void OpenPort()
{
    FT_STATUS ftStatus = FT_OK;
    if(dwOpenFlags == FT_LIST_NUMBER_ONLY)
    {
        int iSelIndex = comboBox1->SelectedIndex;
        if(iSelIndex >= 0)
            ftStatus = FT_Open(iSelIndex, &handle);
    }
    else
    {
        String * str;
        char cBuf[64];
        str = comboBox1->GetItemText(comboBox1->SelectedItem);
        for(int i = 0; i < str->Length; i++)
        {
            cBuf[i] = str->Chars[i];
        }
        ftStatus = FT_OpenEx(cBuf, dwOpenFlags, &handle);
    }
}

System::Void ClosePort()
{
    if(handle)
    {
        FT_Close(handle);
        handle = NULL;
    }
}

System::Void btnSend_Click(System::Object *  sender, System::EventArgs *  e)
{
    FT_STATUS ftStatus = FT_OK;
    DWORD ret;
    int size = 0;
    char cBuf[150];
    String* s;
    float data1 = 0;
    float data2 = 0;
    float data3 = 0;
    char test1 = 0;
    char test2 = 0;
```

```
char test3 = 0;
int angle = 0;
int index = 1;
float newVolt = 0;
float data = 0;

// Get the direct angle value and generate the USB data packet
if(radioDirect->Checked == true)
{
    float tAngle[61][36]={3.5,3.2,2.9,2.6,2.2,1.7,1.0,4.6,4.0,3.7,3.3,3.0,2.7,2.4
    ,1.9,1.2,0.3,4.2,3.8,3.4,3.1,2.8,2.5,2.1,1.5,0.7,4.4,3.9,3.5,3.2,2.9,2.6,2.2,
    1.7,1.0,0.0,
                        3.2,2.9,2.6,2.2,1.7,1.0,0.1,4.1,3.7,3.4,3.1,2.8,2.5,2.1
                        ,1.5,0.7,4.4,4.0,3.6,3.2,3.0,2.7,2.3,1.9,1.2,0.4,4.2,
                        3.8,3.5,3.2,2.9,2.6,2.2,1.6,0.9,0.0,
                        2.9,2.6,2.2,1.7,1.0,0.2,4.1,3.8,3.4,3.2,2.9,2.6,2.2,1.7
                        ,1.0,0.1,4.1,3.7,3.4,3.1,2.8,2.6,2.1,1.6,1.0,0.0,4.1,
                        3.7,3.4,3.1,2.8,2.5,2.1,1.6,0.9,0.0,
                        2.5,2.1,1.6,1.0,0.1,4.2,3.8,3.5,3.2,2.9,2.6,2.3,1.8,1.2
                        ,0.4,4.3,3.9,3.5,3.2,3.0,2.7,2.4,2.0,1.4,0.7,4.4,4.0,
                        3.7,3.3,3.1,2.8,2.5,2.1,1.6,0.9,0.0,
                        2.1,1.6,0.9,0.0,4.1,3.8,3.5,3.2,2.9,2.7,2.3,1.9,1.3,0.6
                        ,4.4,4.0,3.7,3.3,3.1,2.8,2.6,2.2,1.7,1.1,0.3,4.3,3.8,
                        3.5,3.2,3.0,2.7,2.4,2.0,1.5,0.9,0.0,
                        1.4,0.7,4.5,4.1,3.7,3.5,3.2,2.9,2.7,2.4,2.0,1.4,0.8,4.6
                        ,4.1,3.7,3.5,3.2,2.9,2.7,2.4,2.0,1.5,0.8,4.6,4.1,3.8,
                        3.5,3.2,3.0,2.7,2.4,2.0,1.5,0.8,0.0,
                        0.5,4.4,4.0,3.7,3.4,3.2,2.9,2.7,2.4,2.0,1.5,0.9,0.0,4.1
                        ,3.8,3.5,3.2,3.0,2.8,2.5,2.1,1.7,1.1,0.5,4.4,4.0,3.7,
                        3.4,3.1,2.9,2.6,2.3,1.9,1.4,0.8,0.0,
                        4.2,3.8,3.6,3.3,3.1,2.8,2.6,2.3,1.9,1.4,0.9,0.1,4.2,3.8
                        ,3.6,3.3,3.1,2.8,2.6,2.3,1.9,1.4,0.8,0.0,4.2,3.8,3.6,
                        3.3,3.1,2.8,2.6,2.3,1.9,1.4,0.8,0.0,
                        3.7,3.5,3.2,3.0,2.8,2.6,2.2,1.9,1.4,0.8,0.1,4.2,3.8,3.6
                        ,3.3,3.1,2.9,2.7,2.4,2.0,1.6,1.1,0.4,4.4,4.0,3.7,3.5,
                        3.2,3.0,2.8,2.5,2.2,1.8,1.3,0.8,0.0,
                        3.3,3.1,2.9,2.7,2.5,2.1,1.7,1.3,0.7,4.6,4.2,3.8,3.6,3.3
                        ,3.1,2.9,2.7,2.5,2.1,1.7,1.3,0.7,4.6,4.2,3.8,3.6,3.3,
                        3.2,2.9,2.7,2.5,2.1,1.8,1.3,0.7,0.0,
                        3.0,2.8,2.6,2.3,2.0,1.6,1.1,0.5,4.5,4.1,3.8,3.6,3.3,3.1
                        ,2.9,2.7,2.5,2.2,1.8,1.4,0.9,0.2,4.3,4.0,3.7,3.5,3.2,
                        3.1,2.8,2.7,2.4,2.1,1.7,1.3,0.7,0.0,
                        2.7,2.4,2.1,1.8,1.4,0.9,0.2,4.3,4.0,3.8,3.5,3.3,3.1,2.9
                        ,2.7,2.5,2.2,1.9,1.5,1.0,0.5,4.5,4.1,3.8,3.6,3.4,3.2,
                        3.0,2.8,2.6,2.3,2.0,1.6,1.2,0.7,0.0,
                        2.2,1.9,1.5,1.0,0.5,4.5,4.2,3.9,3.7,3.5,3.2,3.1,2.9,2.7
                        ,2.5,2.2,1.9,1.5,1.1,0.6,4.6,4.2,3.9,3.7,3.5,3.2,3.1,
                        2.9,2.7,2.5,2.3,2.0,1.6,1.1,0.6,0.0,
                        1.5,1.1,0.6,0.0,4.3,4.0,3.8,3.6,3.3,3.2,3.0,2.8,2.7,2.5
                        ,2.2,1.9,1.5,1.1,0.6,0.0,4.3,4.0,3.8,3.6,3.3,3.2,3.0,
                        2.8,2.7,2.4,2.2,1.9,1.5,1.1,0.6,0.0,
                        0.6,0.1,4.3,4.0,3.8,3.6,3.4,3.2,3.1,2.9,2.8,2.6,2.4,2.1
                        ,1.8,1.5,1.1,0.6,0.0,4.3,4.0,3.8,3.6,3.4,3.2,3.1,2.9,
                        2.8,2.6,2.4,2.1,1.8,1.5,1.0,0.6,0.0,
                        4.3,4.0,3.8,3.6,3.5,3.2,3.1,3.0,2.8,2.7,2.5,2.3,2.0,1.7
                        ,1.4,1.0,0.5,4.6,4.3,4.0,3.8,3.6,3.5,3.2,3.1,3.0,2.8,
                        2.7,2.5,2.3,2.0,1.7,1.4,1.0,0.5,0.0,
                        3.8,3.6,3.4,3.2,3.1,3.0,2.8,2.7,2.5,2.3,2.1,1.8,1.5,1.2
                        ,0.8,0.4,4.5,4.2,4.0,3.8,3.7,3.5,3.3,3.2,3.0,2.9,2.7,
```

2.6,2.4,2.2,1.9,1.6,1.3,0.9,0.5,0.0,
3.3,3.2,3.1,2.9,2.8,2.7,2.5,2.3,2.1,1.9,1.6,1.3,1.0,0.6
,0.1,4.4,4.1,3.9,3.8,3.6,3.5,3.3,3.2,3.1,2.9,2.8,2.6,
2.5,2.3,2.1,1.8,1.5,1.2,0.9,0.5,0.0,
3.0,2.9,2.7,2.6,2.5,2.3,2.1,1.9,1.6,1.3,1.0,0.7,0.2,4.5
,4.2,4.0,3.8,3.7,3.6,3.4,3.2,3.2,3.1,2.9,2.8,2.7,2.5,
2.4,2.2,2.0,1.7,1.5,1.1,0.8,0.4,0.0,
2.6,2.5,2.3,2.1,2.0,1.7,1.5,1.2,0.9,0.6,0.2,4.5,4.3,4.1
,3.9,3.8,3.6,3.5,3.4,3.2,3.2,3.1,2.9,2.8,2.7,2.6,2.4,
2.2,2.1,1.8,1.6,1.4,1.1,0.8,0.4,0.0,
2.1,2.0,1.7,1.5,1.3,1.0,0.7,0.4,0.0,4.4,4.2,4.0,3.9,3.8
,3.7,3.5,3.4,3.3,3.2,3.1,3.0,2.9,2.8,2.7,2.6,2.4,2.3,
2.1,1.9,1.7,1.5,1.3,1.0,0.7,0.4,0.0,
1.4,1.2,1.0,0.7,0.4,0.0,4.4,4.2,4.1,4.0,3.8,3.7,3.6,3.5
,3.4,3.3,3.2,3.1,3.0,2.9,2.8,2.7,2.6,2.5,2.4,2.3,2.1,
2.0,1.8,1.6,1.4,1.2,0.9,0.6,0.3,0.0,
0.4,0.1,4.5,4.3,4.2,4.1,3.9,3.8,3.7,3.6,3.5,3.4,3.3,3.2
,3.2,3.1,3.0,2.9,2.8,2.8,2.7,2.6,2.5,2.4,2.2,2.1,2.0,
1.8,1.6,1.5,1.3,1.0,0.8,0.6,0.3,0.0,
4.1,4.0,3.9,3.8,3.7,3.7,3.6,3.5,3.4,3.3,3.2,3.2,3.1,3.1
,3.0,2.9,2.8,2.7,2.7,2.6,2.5,2.4,2.3,2.2,2.1,1.9,1.8,
1.6,1.5,1.3,1.1,0.9,0.7,0.5,0.2,0.0,
3.7,3.6,3.5,3.5,3.4,3.3,3.2,3.2,3.1,3.1,3.0,2.9,2.9,2.8
,2.7,2.7,2.6,2.5,2.5,2.4,2.3,2.2,2.1,2.0,1.9,1.7,1.6,
1.5,1.3,1.2,1.0,0.8,0.6,0.4,0.2,0.0,
3.2,3.2,3.2,3.1,3.1,3.0,2.9,2.9,2.8,2.8,2.7,2.7,2.6,2.6
,2.5,2.4,2.4,2.3,2.2,2.1,2.0,1.9,1.8,1.7,1.6,1.5,1.4,
1.3,1.1,1.0,0.9,0.7,0.5,0.4,0.2,0.0,
2.9,2.8,2.8,2.8,2.7,2.7,2.6,2.6,2.5,2.5,2.4,2.4,2.3,2.2
,2.2,2.1,2.0,2.0,1.9,1.8,1.7,1.6,1.6,1.5,1.4,1.3,1.2,
1.0,0.9,0.8,0.7,0.6,0.4,0.3,0.1,0.0,
2.5,2.5,2.4,2.4,2.3,2.3,2.2,2.2,2.1,2.1,2.0,2.0,1.9,1.9
,1.8,1.7,1.7,1.6,1.5,1.5,1.4,1.3,1.2,1.2,1.1,1.0,0.9,
0.8,0.7,0.6,0.6,0.4,0.3,0.2,0.1,0.0,
1.9,1.9,1.9,1.8,1.8,1.7,1.7,1.6,1.6,1.6,1.5,1.5,1.4,1.4
,1.3,1.3,1.2,1.2,1.1,1.0,1.0,0.9,0.9,0.8,0.8,0.7,0.6,
0.6,0.5,0.4,0.4,0.3,0.2,0.1,0.1,0.0,
1.1,1.1,1.1,1.0,1.0,1.0,1.0,0.9,0.9,0.9,0.9,0.8,0.8,0.8
,0.7,0.7,0.7,0.6,0.6,0.6,0.6,0.5,0.5,0.4,0.4,0.4,0.3,
0.3,0.2,0.2,0.2,0.1,0.1,0.1,0.0,0.0,
0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0
,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,
0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,0.0,
0.0,0.0,0.1,0.1,0.1,0.2,0.2,0.2,0.3,0.3,0.4,0.4,0.4,0.5
,0.5,0.6,0.6,0.6,0.6,0.7,0.7,0.7,0.8,0.8,0.8,0.9,0.9,
0.9,0.9,1.0,1.0,1.0,1.0,1.1,1.1,1.1,
0.0,0.1,0.1,0.2,0.3,0.4,0.4,0.5,0.6,0.6,0.7,0.8,0.8,0.9
,0.9,1.0,1.0,1.1,1.2,1.2,1.3,1.3,1.4,1.4,1.5,1.5,1.6,
1.6,1.6,1.7,1.7,1.8,1.8,1.9,1.9,1.9,
0.0,0.1,0.2,0.3,0.4,0.6,0.6,0.7,0.8,0.9,1.0,1.1,1.2,1.2
,1.3,1.4,1.5,1.5,1.6,1.7,1.7,1.8,1.9,1.9,2.0,2.0,2.1,
2.1,2.2,2.2,2.3,2.3,2.4,2.4,2.5,2.5,
0.0,0.1,0.3,0.4,0.6,0.7,0.8,0.9,1.0,1.2,1.3,1.4,1.5,1.6
,1.6,1.7,1.8,1.9,2.0,2.0,2.1,2.2,2.2,2.3,2.4,2.4,2.5,
2.5,2.6,2.6,2.7,2.7,2.8,2.8,2.8,2.9,
0.0,0.2,0.4,0.5,0.7,0.9,1.0,1.1,1.3,1.4,1.5,1.6,1.7,1.8
,1.9,2.0,2.1,2.2,2.3,2.4,2.4,2.5,2.6,2.6,2.7,2.7,2.8,
2.8,2.9,2.9,3.0,3.1,3.1,3.2,3.2,3.2,
0.0,0.2,0.4,0.6,0.8,1.0,1.2,1.3,1.5,1.6,1.7,1.9,2.0,2.1

,2.2,2.3,2.4,2.5,2.5,2.6,2.7,2.7,2.8,2.9,2.9,3.0,3.1,
3.1,3.2,3.2,3.3,3.4,3.5,3.5,3.6,3.7,
0.0,0.2,0.5,0.7,0.9,1.1,1.3,1.5,1.6,1.8,1.9,2.1,2.2,2.3
,2.4,2.5,2.6,2.7,2.7,2.8,2.9,3.0,3.1,3.1,3.2,3.2,3.3,
3.4,3.5,3.6,3.7,3.7,3.8,3.9,4.0,4.1,
0.0,0.3,0.6,0.8,1.0,1.3,1.5,1.6,1.8,2.0,2.1,2.2,2.4,2.5
,2.6,2.7,2.8,2.8,2.9,3.0,3.1,3.2,3.2,3.3,3.4,3.5,3.6,
3.7,3.8,3.9,4.1,4.2,4.3,4.5,0.1,0.4,
0.0,0.3,0.6,0.9,1.2,1.4,1.6,1.8,2.0,2.1,2.3,2.4,2.5,2.6
,2.7,2.8,2.9,3.0,3.1,3.2,3.3,3.4,3.5,3.6,3.7,3.8,4.0,
4.1,4.2,4.4,0.0,0.4,0.7,1.0,1.2,1.4,
0.0,0.4,0.7,1.0,1.3,1.5,1.7,1.9,2.1,2.3,2.4,2.6,2.7,2.8
,2.9,3.0,3.1,3.2,3.3,3.4,3.5,3.7,3.8,3.9,4.0,4.2,4.4,
0.0,0.4,0.7,1.0,1.3,1.5,1.7,2.0,2.1,
0.0,0.4,0.8,1.1,1.4,1.6,1.8,2.1,2.2,2.4,2.6,2.7,2.8,2.9
,3.1,3.2,3.2,3.4,3.5,3.6,3.8,3.9,4.1,4.3,4.5,0.2,0.6,
0.9,1.2,1.5,1.7,2.0,2.1,2.3,2.5,2.6,
0.0,0.4,0.8,1.1,1.5,1.7,2.0,2.2,2.4,2.5,2.7,2.8,2.9,3.1
,3.2,3.2,3.4,3.6,3.7,3.8,4.0,4.2,4.5,0.2,0.7,1.0,1.3,
1.6,1.9,2.1,2.3,2.5,2.6,2.7,2.9,3.0,
0.0,0.5,0.9,1.2,1.5,1.8,2.1,2.3,2.5,2.6,2.8,2.9,3.1,3.2
,3.3,3.5,3.6,3.8,3.9,4.1,4.4,0.1,0.6,1.0,1.3,1.6,1.9,
2.1,2.3,2.5,2.7,2.8,2.9,3.1,3.2,3.3,
0.0,0.5,0.9,1.3,1.6,1.9,2.2,2.4,2.6,2.7,2.9,3.0,3.2,3.3
,3.5,3.7,3.8,4.0,4.2,4.5,0.4,0.8,1.2,1.5,1.8,2.1,2.3,
2.5,2.7,2.8,3.0,3.1,3.2,3.4,3.6,3.8,
0.0,0.5,1.0,1.4,1.7,2.0,2.3,2.5,2.7,2.8,3.0,3.1,3.2,3.5
,3.6,3.8,4.0,4.3,4.6,0.5,1.0,1.4,1.7,2.0,2.3,2.5,2.7,
2.8,3.0,3.1,3.2,3.5,3.6,3.8,4.0,4.3,
0.0,0.6,1.0,1.5,1.8,2.1,2.4,2.6,2.8,2.9,3.1,3.2,3.4,3.6
,3.8,4.0,4.3,0.0,0.6,1.1,1.5,1.8,2.1,2.4,2.6,2.8,2.9,
3.1,3.2,3.4,3.6,3.8,4.0,4.3,0.1,0.6,
0.0,0.6,1.1,1.5,1.9,2.2,2.4,2.7,2.8,3.0,3.2,3.3,3.6,3.8
,4.0,4.3,0.0,0.6,1.1,1.5,1.9,2.2,2.5,2.7,2.8,3.0,3.2,
3.3,3.6,3.8,4.0,4.3,0.0,0.6,1.1,1.5,
0.0,0.6,1.1,1.6,2.0,2.3,2.5,2.7,2.9,3.1,3.2,3.5,3.7,3.9
,4.2,4.6,0.6,1.1,1.5,1.9,2.2,2.5,2.7,2.9,3.1,3.2,3.5,
3.7,3.9,4.2,4.5,0.5,1.0,1.5,1.9,2.2,
0.0,0.7,1.2,1.6,2.0,2.3,2.6,2.8,3.0,3.2,3.4,3.6,3.8,4.1
,4.5,0.5,1.0,1.5,1.9,2.2,2.5,2.7,2.9,3.1,3.3,3.5,3.8,
4.0,4.3,0.2,0.9,1.4,1.8,2.1,2.4,2.7,
0.0,0.7,1.3,1.7,2.1,2.4,2.7,2.8,3.1,3.2,3.5,3.7,4.0,4.3
,0.2,0.9,1.4,1.8,2.2,2.5,2.7,2.9,3.1,3.3,3.6,3.8,4.1,
4.5,0.5,1.1,1.6,2.0,2.3,2.6,2.8,3.0,
0.0,0.7,1.3,1.8,2.1,2.5,2.7,2.9,3.2,3.3,3.6,3.8,4.2,4.6
,0.7,1.3,1.7,2.1,2.5,2.7,2.9,3.1,3.3,3.6,3.8,4.2,4.6,
0.7,1.3,1.7,2.1,2.5,2.7,2.9,3.1,3.3,
0.0,0.8,1.3,1.8,2.2,2.5,2.8,3.0,3.2,3.5,3.7,4.0,4.4,0.4
,1.1,1.6,2.0,2.4,2.7,2.9,3.1,3.3,3.6,3.8,4.2,0.1,0.8,
1.4,1.9,2.2,2.6,2.8,3.0,3.2,3.5,3.7,
0.0,0.8,1.4,1.9,2.3,2.6,2.8,3.1,3.3,3.6,3.8,4.2,0.0,0.8
,1.4,1.9,2.3,2.6,2.8,3.1,3.3,3.6,3.8,4.2,0.1,0.9,1.4,
1.9,2.3,2.6,2.8,3.1,3.3,3.6,3.8,4.2,
0.0,0.8,1.4,1.9,2.3,2.6,2.9,3.1,3.4,3.7,4.0,4.4,0.5,1.1
,1.7,2.1,2.5,2.8,3.0,3.2,3.5,3.8,4.1,0.0,0.9,1.5,2.0,
2.4,2.7,2.9,3.2,3.4,3.7,4.0,4.4,0.5,
0.0,0.8,1.5,2.0,2.4,2.7,3.0,3.2,3.5,3.8,4.1,4.6,0.8,1.5
,2.0,2.4,2.7,2.9,3.2,3.5,3.7,4.1,4.6,0.8,1.4,2.0,2.4,
2.7,2.9,3.2,3.5,3.7,4.1,4.5,0.7,1.4,

```
                                0.0,0.9,1.5,2.0,2.4,2.7,3.0,3.2,3.5,3.8,4.3,0.3,1.1,1.7
                                ,2.2,2.6,2.8,3.1,3.3,3.7,4.0,4.4,0.6,1.3,1.9,2.3,2.7,
                                2.9,3.2,3.5,3.8,4.1,0.0,0.9,1.6,2.1,
                                0.0,0.9,1.6,2.1,2.5,2.8,3.1,3.3,3.7,4.0,4.4,0.7,1.4,2.0
                                ,2.4,2.7,3.0,3.2,3.5,3.9,4.3,0.4,1.2,1.8,2.3,2.6,2.9,
                                3.2,3.5,3.8,4.2,0.1,1.0,1.6,2.1,2.5,
                                0.0,0.9,1.6,2.1,2.5,2.8,3.1,3.4,3.7,4.1,0.0,1.0,1.6,2.1
                                ,2.6,2.8,3.1,3.4,3.7,4.1,0.1,1.0,1.7,2.2,2.6,2.9,3.2,
                                3.4,3.8,4.1,0.2,1.0,1.7,2.2,2.6,2.9,
                                0.0,0.9,1.6,2.2,2.6,2.9,3.2,3.5,3.8,4.2,0.4,1.2,1.9,2.3
                                ,2.7,3.0,3.2,3.6,4.0,4.4,0.7,1.5,2.1,2.5,2.8,3.1,3.4,
                                3.7,4.1,0.1,1.0,1.7,2.2,2.6,2.9,3.2,
                                0.0,1.0,1.7,2.2,2.6,2.9,3.2,3.5,3.9,4.4,0.7,1.5,2.1,2.5
                                ,2.8,3.1,3.4,3.8,4.2,0.3,1.2,1.9,2.4,2.7,3.0,3.3,3.7,
                                4.0,4.6,1.0,1.7,2.2,2.6,2.9,3.2,3.5};

        s = textBoxAngle->Text;

        cBuf[0] = 0xC2;
        angle = Convert::ToInt32(s);
        angle += 31;

        for(int i = 0; i<36;i++)
        {
            newVolt = tAngle[angle-1][i];

            cBuf[index] = ((int)(newVolt))+48;
            cBuf[index+1] = '.';

            data = (int)((System::Math::Round(newVolt*10))-(((int)(newVolt))*10));

            cBuf[index+2] = ((char)data)+48;

            index +=3;
        }
        size = 37*3;
    }
    // Get the same voltage value and generate the USB data packet
    else if(radioSameV->Checked == true)
    {
        size = textBoxSameV->TextLength;
        s = textBoxSameV->Text;
        cBuf[0] = 0x0E;
        for(int i = 1; i<size+1;i++)
        {
            cBuf[i] = s->String::Chars[i-1];
        }
        size++;
    }
    // Get the different voltage value and generate the USB data packet
    else if(radioDiffV->Checked == true)
    {
        int i = 1;
        cBuf[0] = 0x02;

        size = 0;
        size = textBox3->TextLength;
        if(size>0)
        {
```

```
    s = textBox3->Text;
    for(int j = 0;j<size;j++)
    {
        cBuf[i] = s->String::Chars[j];
        i++;
    }
}
else
{
    cBuf[i] = '9';
    cBuf[i+1] = '.';
    cBuf[i+2] = '9';
    i+=3;
}

size = 0;
size = textBox4->TextLength;
if(size>0)
{
    s = textBox4->Text;
    for(int j = 0;j<size;j++)
    {
        cBuf[i] = s->String::Chars[j];
        i++;
    }
}
else
{
    cBuf[i] = '9';
    cBuf[i+1] = '.';
    cBuf[i+2] = '9';
    i+=3;
}

size = 0;
size = textBox5->TextLength;
if(size>0)
{
    s = textBox5->Text;
    for(int j = 0;j<size;j++)
    {
        cBuf[i] = s->String::Chars[j];
        i++;
    }
}
else
{
    cBuf[i] = '9';
    cBuf[i+1] = '.';
    cBuf[i+2] = '9';
    i+=3;
}

size = 0;
size = textBox6->TextLength;
if(size>0)
{
    s = textBox6->Text;
    for(int j = 0;j<size;j++)
```

```
    {
        cBuf[i] = s->String::Chars[j];
        i++;
    }
}
else
{
    cBuf[i] = '9';
    cBuf[i+1] = '.';
    cBuf[i+2] = '9';
    i+=3;
}

size = 0;
size = textBox7->TextLength;
if(size>0)
{
    s = textBox7->Text;
    for(int j = 0;j<size;j++)
    {
        cBuf[i] = s->String::Chars[j];
        i++;
    }
}
else
{
    cBuf[i] = '9';
    cBuf[i+1] = '.';
    cBuf[i+2] = '9';
    i+=3;
}

size = 0;
size = textBox8->TextLength;
if(size>0)
{
    s = textBox8->Text;
    for(int j = 0;j<size;j++)
    {
        cBuf[i] = s->String::Chars[j];
        i++;
    }
}
else
{
    cBuf[i] = '9';
    cBuf[i+1] = '.';
    cBuf[i+2] = '9';
    i+=3;
}

size = 0;
size = textBox12->TextLength;
if(size>0)
{
    s = textBox12->Text;
    for(int j = 0;j<size;j++)
    {
        cBuf[i] = s->String::Chars[j];
```

```
            i++;
        }
    }
    else
    {
        cBuf[i] = '9';
        cBuf[i+1] = '.';
        cBuf[i+2] = '9';
        i+=3;
    }

    size = 0;
    size = textBox11->TextLength;
    if(size>0)
    {
        s = textBox11->Text;
        for(int j = 0;j<size;j++)
        {
            cBuf[i] = s->String::Chars[j];
            i++;
        }
    }
    else
    {
        cBuf[i] = '9';
        cBuf[i+1] = '.';
        cBuf[i+2] = '9';
        i+=3;
    }

    size = 0;
    size = textBox10->TextLength;
    if(size>0)
    {
        s = textBox10->Text;
        for(int j = 0;j<size;j++)
        {
            cBuf[i] = s->String::Chars[j];
            i++;
        }
    }
    else
    {
        cBuf[i] = '9';
        cBuf[i+1] = '.';
        cBuf[i+2] = '9';
        i+=3;
    }

    size = 0;
    size = textBox9->TextLength;
    if(size>0)
    {
        s = textBox9->Text;
        for(int j = 0;j<size;j++)
        {
            cBuf[i] = s->String::Chars[j];
            i++;
        }
```

```
}
else
{
    cBuf[i] = '9';
    cBuf[i+1] = '.';
    cBuf[i+2] = '9';
    i+=3;
}

size = 0;
size = textBox22->TextLength;
if(size>0)
{
    s = textBox22->Text;
    for(int j = 0;j<size;j++)
    {
        cBuf[i] = s->String::Chars[j];
        i++;
    }
}
else
{
    cBuf[i] = '9';
    cBuf[i+1] = '.';
    cBuf[i+2] = '9';
    i+=3;
}

size = 0;
size = textBox21->TextLength;
if(size>0)
{
    s = textBox21->Text;
    for(int j = 0;j<size;j++)
    {
        cBuf[i] = s->String::Chars[j];
        i++;
    }
}
else
{
    cBuf[i] = '9';
    cBuf[i+1] = '.';
    cBuf[i+2] = '9';
    i+=3;
}

size = 0;
size = textBox20->TextLength;
if(size>0)
{
    s = textBox20->Text;
    for(int j = 0;j<size;j++)
    {
        cBuf[i] = s->String::Chars[j];
        i++;
    }
}
else
```

```
{
    cBuf[i] = '9';
    cBuf[i+1] = '.';
    cBuf[i+2] = '9';
    i+=3;
}

size = 0;
size = textBox19->TextLength;
if(size>0)
{
    s = textBox19->Text;
    for(int j = 0;j<size;j++)
    {
        cBuf[i] = s->String::Chars[j];
        i++;
    }
}
else
{
    cBuf[i] = '9';
    cBuf[i+1] = '.';
    cBuf[i+2] = '9';
    i+=3;
}

size = 0;
size = textBox18->TextLength;
if(size>0)
{
    s = textBox18->Text;
    for(int j = 0;j<size;j++)
    {
        cBuf[i] = s->String::Chars[j];
        i++;
    }
}
else
{
    cBuf[i] = '9';
    cBuf[i+1] = '.';
    cBuf[i+2] = '9';
    i+=3;
}

size = 0;
size = textBox17->TextLength;
if(size>0)
{
    s = textBox17->Text;
    for(int j = 0;j<size;j++)
    {
        cBuf[i] = s->String::Chars[j];
        i++;
    }
}
else
{
    cBuf[i] = '9';
```

```
    cBuf[i+1] = '.';
    cBuf[i+2] = '9';
    i+=3;
}

size = 0;
size = textBox16->TextLength;
if(size>0)
{
    s = textBox16->Text;
    for(int j = 0;j<size;j++)
    {
        cBuf[i] = s->String::Chars[j];
        i++;
    }
}
else
{
    cBuf[i] = '9';
    cBuf[i+1] = '.';
    cBuf[i+2] = '9';
    i+=3;
}

size = 0;
size = textBox15->TextLength;
if(size>0)
{
    s = textBox15->Text;
    for(int j = 0;j<size;j++)
    {
        cBuf[i] = s->String::Chars[j];
        i++;
    }
}
else
{
    cBuf[i] = '9';
    cBuf[i+1] = '.';
    cBuf[i+2] = '9';
    i+=3;
}

size = 0;
size = textBox14->TextLength;
if(size>0)
{
    s = textBox14->Text;
    for(int j = 0;j<size;j++)
    {
        cBuf[i] = s->String::Chars[j];
        i++;
    }
}
else
{
    cBuf[i] = '9';
    cBuf[i+1] = '.';
    cBuf[i+2] = '9';
```

```
    i+=3;
}

size = 0;
size = textBox13->TextLength;
if(size>0)
{
    s = textBox13->Text;
    for(int j = 0;j<size;j++)
    {
        cBuf[i] = s->String::Chars[j];
        i++;
    }
}
else
{
    cBuf[i] = '9';
    cBuf[i+1] = '.';
    cBuf[i+2] = '9';
    i+=3;
}

size = 0;
size = textBox42->TextLength;
if(size>0)
{
    s = textBox42->Text;
    for(int j = 0;j<size;j++)
    {
        cBuf[i] = s->String::Chars[j];
        i++;
    }
}
else
{
    cBuf[i] = '9';
    cBuf[i+1] = '.';
    cBuf[i+2] = '9';
    i+=3;
}

size = 0;
size = textBox41->TextLength;
if(size>0)
{
    s = textBox41->Text;
    for(int j = 0;j<size;j++)
    {
        cBuf[i] = s->String::Chars[j];
        i++;
    }
}
else
{
    cBuf[i] = '9';
    cBuf[i+1] = '.';
    cBuf[i+2] = '9';
    i+=3;
}
```

```
size = 0;
size = textBox40->TextLength;
if(size>0)
{
    s = textBox40->Text;
    for(int j = 0;j<size;j++)
    {
        cBuf[i] = s->String::Chars[j];
        i++;
    }
}
else
{
    cBuf[i] = '9';
    cBuf[i+1] = '.';
    cBuf[i+2] = '9';
    i+=3;
}

size = 0;
size = textBox39->TextLength;
if(size>0)
{
    s = textBox39->Text;
    for(int j = 0;j<size;j++)
    {
        cBuf[i] = s->String::Chars[j];
        i++;
    }
}
else
{
    cBuf[i] = '9';
    cBuf[i+1] = '.';
    cBuf[i+2] = '9';
    i+=3;
}

size = 0;
size = textBox38->TextLength;
if(size>0)
{
    s = textBox38->Text;
    for(int j = 0;j<size;j++)
    {
        cBuf[i] = s->String::Chars[j];
        i++;
    }
}
else
{
    cBuf[i] = '9';
    cBuf[i+1] = '.';
    cBuf[i+2] = '9';
    i+=3;
}

size = 0;
```

```
size = textBox37->TextLength;
if(size>0)
{
    s = textBox37->Text;
    for(int j = 0;j<size;j++)
    {
        cBuf[i] = s->String::Chars[j];
        i++;
    }
}
else
{
    cBuf[i] = '9';
    cBuf[i+1] = '.';
    cBuf[i+2] = '9';
    i+=3;
}

size = 0;
size = textBox36->TextLength;
if(size>0)
{
    s = textBox36->Text;
    for(int j = 0;j<size;j++)
    {
        cBuf[i] = s->String::Chars[j];
        i++;
    }
}
else
{
    cBuf[i] = '9';
    cBuf[i+1] = '.';
    cBuf[i+2] = '9';
    i+=3;
}

size = 0;
size = textBox35->TextLength;
if(size>0)
{
    s = textBox35->Text;
    for(int j = 0;j<size;j++)
    {
        cBuf[i] = s->String::Chars[j];
        i++;
    }
}
else
{
    cBuf[i] = '9';
    cBuf[i+1] = '.';
    cBuf[i+2] = '9';
    i+=3;
}

size = textBox34->TextLength;
if(size>0)
{
```

```
    s = textBox34->Text;
    for(int j = 0;j<size;j++)
    {
        cBuf[i] = s->String::Chars[j];
        i++;
    }
}
else
{
    cBuf[i] = '9';
    cBuf[i+1] = '.';
    cBuf[i+2] = '9';
    i+=3;
}

size = 0;
size = textBox33->TextLength;
if(size>0)
{
    s = textBox33->Text;
    for(int j = 0;j<size;j++)
    {
        cBuf[i] = s->String::Chars[j];
        i++;
    }
}
else
{
    cBuf[i] = '9';
    cBuf[i+1] = '.';
    cBuf[i+2] = '9';
    i+=3;
}

size = 0;
size = textBox32->TextLength;
if(size>0)
{
    s = textBox32->Text;
    for(int j = 0;j<size;j++)
    {
        cBuf[i] = s->String::Chars[j];
        i++;
    }
}
else
{
    cBuf[i] = '9';
    cBuf[i+1] = '.';
    cBuf[i+2] = '9';
    i+=3;
}

size = 0;
size = textBox31->TextLength;
if(size>0)
{
    s = textBox31->Text;
    for(int j = 0;j<size;j++)
```

```
    {
        cBuf[i] = s->String::Chars[j];
        i++;
    }
}
else
{
    cBuf[i] = '9';
    cBuf[i+1] = '.';
    cBuf[i+2] = '9';
    i+=3;
}

size = 0;
size = textBox30->TextLength;
if(size>0)
{
    s = textBox30->Text;
    for(int j = 0;j<size;j++)
    {
        cBuf[i] = s->String::Chars[j];
        i++;
    }
}
else
{
    cBuf[i] = '9';
    cBuf[i+1] = '.';
    cBuf[i+2] = '9';
    i+=3;
}

size = 0;
size = textBox29->TextLength;
if(size>0)
{
    s = textBox29->Text;
    for(int j = 0;j<size;j++)
    {
        cBuf[i] = s->String::Chars[j];
        i++;
    }
}
else
{
    cBuf[i] = '9';
    cBuf[i+1] = '.';
    cBuf[i+2] = '9';
    i+=3;
}

size = 0;
size = textBox28->TextLength;
if(size>0)
{
    s = textBox28->Text;
    for(int j = 0;j<size;j++)
    {
        cBuf[i] = s->String::Chars[j];
```

```
            i++;
        }
    }
    else
    {
        cBuf[i] = '9';
        cBuf[i+1] = '.';
        cBuf[i+2] = '9';
        i+=3;
    }

    size = 0;
    size = textBox27->TextLength;
    if(size>0)
    {
        s = textBox27->Text;
        for(int j = 0;j<size;j++)
        {
            cBuf[i] = s->String::Chars[j];
            i++;
        }
    }
    else
    {
        cBuf[i] = '9';
        cBuf[i+1] = '.';
        cBuf[i+2] = '9';
        i+=3;
    }

    size = 0;
    size = textBox26->TextLength;
    if(size>0)
    {
        s = textBox26->Text;
        for(int j = 0;j<size;j++)
        {
            cBuf[i] = s->String::Chars[j];
            i++;
        }
    }
    else
    {
        cBuf[i] = '9';
        cBuf[i+1] = '.';
        cBuf[i+2] = '9';
        i+=3;
    }

    size = i;
}
else
{}


if(handle == NULL) {
    OpenPort();
}
if(handle) {
```

```
        StartThread();                                  // Create and start the reader
        thread
        ftStatus = FT_SetEventNotification(handle, FT_EVENT_RXCHAR, hEvent); // Set
        the notification event
        ftStatus = FT_SetBaudRate(handle, 9600);        // Set the baud rate, 9600
        ftStatus = FT_Write(handle, cBuf, size, &ret);  // Wrtie into the USB
        controller
    }
    else {
        MessageBox::Show("Open Failed");
        return;
    }

    System::Threading::Thread::Sleep(1000);
    WaitForSingleObject(DEvent, -1);

    listBox1->Items->Clear();                           // Clear the feedback display

    // Update the display
    for(int i=1;i<112;i+=3)
    {
        // Read the three byte standing for the voltage valut
        test1 = buf[i];
        test2 = buf[i+1];
        test3 = buf[i+2];

        data1 = test1-48;                               // Read digit before the virgule
        data2 = (float)(test3-48)/10;                   // Read digit after the virgule
        data3 = data1 + data2;

        s = Convert::ToString(data3);                   // Convert voltage to string type
        this->listBox1->Items->Add(s);                  // Add voltage value to the list
        box
        data1 = data2 = data3 = 0;                      // Reset data variable
    }
}

System::Void FillComboBox(UInt32 dwDescFlags)
{
    FT_STATUS ftStatus;
    UInt32 numDevs;
    void * p1;

    comboBox1->Items->Clear();

    p1 = (void*)&numDevs;
    ftStatus = FT_ListDevices(p1, NULL, FT_LIST_NUMBER_ONLY);

    if(ftStatus == 0)
    {
        char cBuf[64];
        if (ftStatus == 0)
        {
            UInt32 uDevNo;
            for(uDevNo=0; uDevNo<numDevs; uDevNo++)
            {
                String * str;
                if(dwDescFlags == FT_LIST_NUMBER_ONLY) {
                    str = Convert::ToString(uDevNo);
```

```
                    comboBox1->Items->Add(str);
                }
                else {
                    ftStatus = FT_ListDevices(uDevNo, cBuf, dwDescFlags);
                    str = Convert::ToString(cBuf);
                    comboBox1->Items->Add(str);
                }
            }
            if(comboBox1->Items->Count > 0) {
                comboBox1->SelectedIndex = 0;
            }
        }
    }
}

System::Void StopThread()
{
    bContinue = false;
    if(hEvent)      // let the thread come out of waiting for infinite time
        SetEvent(hEvent);
    if(thrdReader && thrdReader->IsAlive) { // stop it
        TimeSpan waitTime = TimeSpan(0, 0, 1);  // 1 second timeout
        if(thrdReader->Join(waitTime) != true) {
            thrdReader->Abort();    // didnt stop the thread - take more drastic
            action
        }
    }
}

System::Void StartThread()
{
    // Create a reader thread here
    thrdReader = new Thread(new ThreadStart(this, &USBFT245R::Form1::ReadingProc));
    bContinue = true;
    thrdReader->Start();
    while (!thrdReader->IsAlive);   // wait for the thread to start
    Thread::Sleep(1000);
}

System::Void Form1_Load(System::Object *  sender, System::EventArgs *  e)
{
    handle = NULL;
    hEvent = CreateEvent(NULL, FALSE, FALSE, "");
    radioDescription->Checked = true;
    radioDirect->Checked = true;
}

System::Void comboBox1_SelectedIndexChanged(System::Object *  sender, System::
EventArgs *  e)
{
    ClosePort();
    OpenPort();
}

System::Void radioNumber_CheckedChanged(System::Object *  sender, System::EventArgs *
  e)
{
    if(radioNumber->Checked)
    {
```

```
            ClosePort();
            dwOpenFlags = FT_LIST_NUMBER_ONLY;
            FillComboBox(dwOpenFlags);
        }
    }

    System::Void radioDescription_CheckedChanged(System::Object *  sender, System::
    EventArgs *  e)
    {
        if(radioDescription->Checked) {
            ClosePort();
            dwOpenFlags = FT_OPEN_BY_DESCRIPTION;
            FillComboBox(FT_LIST_BY_INDEX | dwOpenFlags);
        }
    }

    System::Void radioSerial_CheckedChanged(System::Object *  sender, System::EventArgs *
      e)
    {
        if(radioSerial->Checked) {
            ClosePort();
            dwOpenFlags = FT_OPEN_BY_SERIAL_NUMBER;
            FillComboBox(FT_LIST_BY_INDEX | dwOpenFlags);
        }
    }

    System::Void radioDirect_CheckedChanged(System::Object*  sender, System::EventArgs*
    e)
    {
        if(radioDirect->Checked)
        {
            textBoxAngle->Enabled = true;
            textBoxSameV->Enabled = false;
            setVoltageTextBox(false);
        }
    }

    System::Void radioSameV_CheckedChanged(System::Object*  sender, System::EventArgs*  e)
    {
        if(radioSameV->Checked)
        {
            textBoxAngle->Enabled = false;
            textBoxSameV->Enabled = true;
            setVoltageTextBox(false);
        }
    }

    System::Void radioDiffV_CheckedChanged(System::Object*  sender, System::EventArgs*  e)
    {
        if(radioDiffV->Checked)
        {
            textBoxAngle->Enabled = false;
            textBoxSameV->Enabled = false;
            setVoltageTextBox(true);
        }
    }
};
}
```